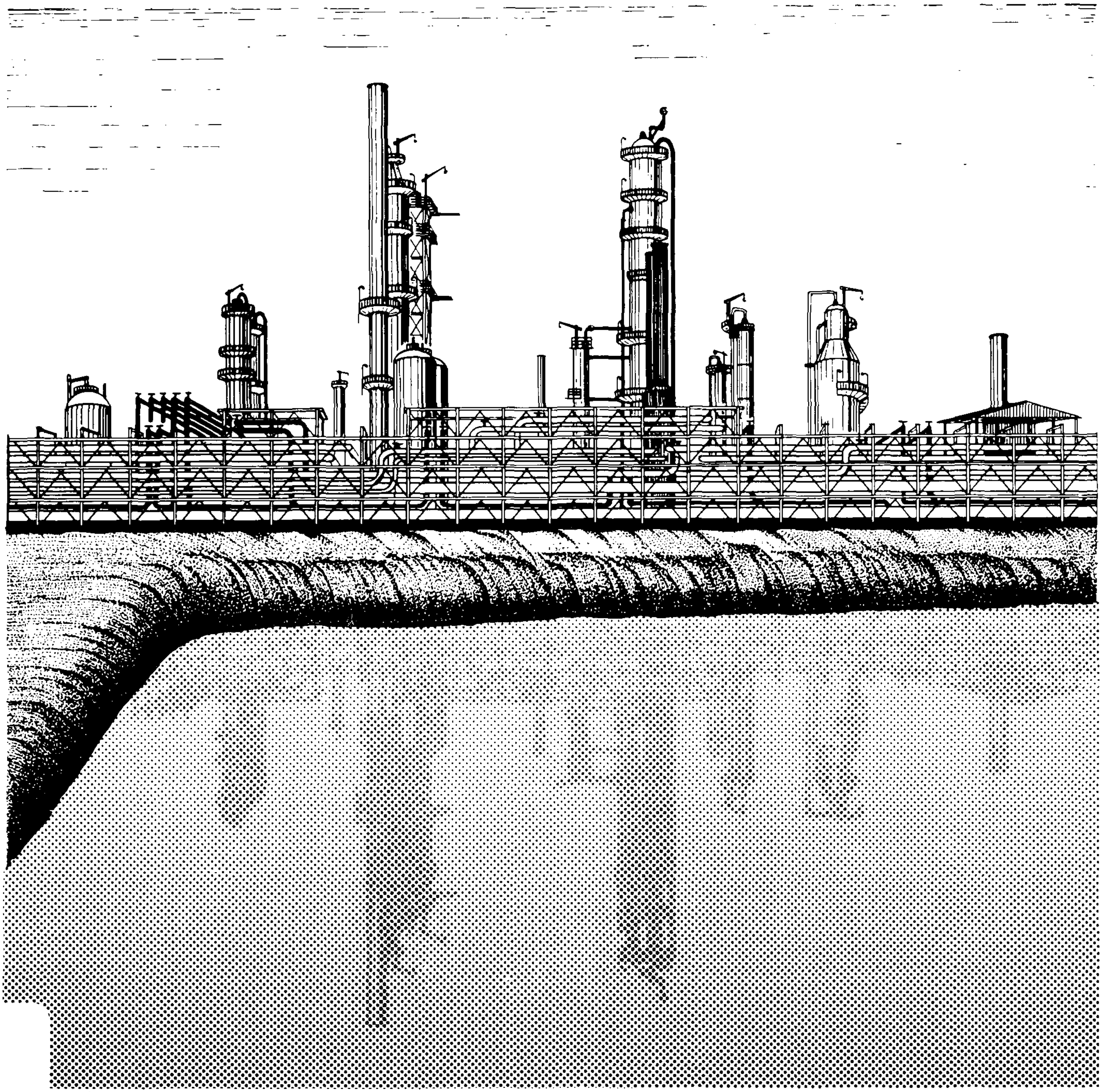
Environmental Status Report for the Canadian Petroleum Refining Industry 1983-1984

Report EPS 1/PN/1
December 1987

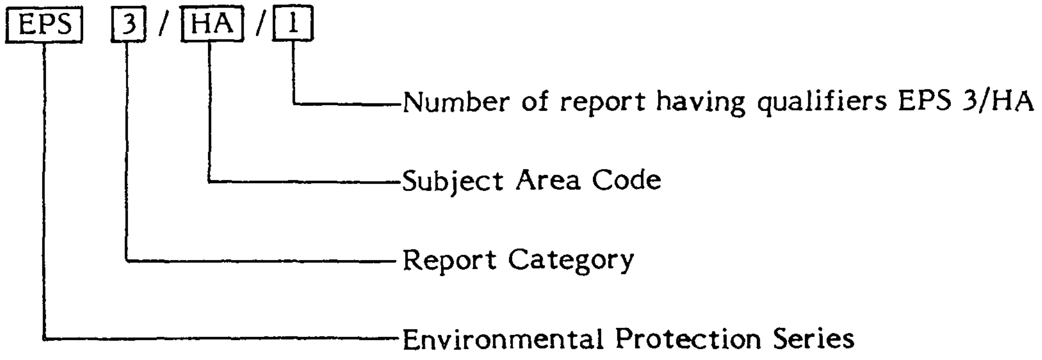


Environment Canada Environnement Canada

Canada

ENVIRONMENTAL PROTECTION SERIES REPORTS

Sample Number:



Categories

1	Regulations/Guidelines/Codes of Practice
2	Public Consultation: Problem Assessment, Control Options
3	Research and Technology Development
4	Literature Reviews
5	Surveys
6	Social, Economic and Environmental Impact Assessments
7	Surveillance
8	Policy Proposals & Statements
9	Manuals

Subject Areas

AG	Agriculture
AP	Airborne Pollutants
AT	Aquatic Toxicity
CC	Commercial Chemicals
CE	Consumers and the Environment
CI	Chemical Industries
FA	Federal Activities
FP	Food Processing
HA	Hazardous Wastes
IC	Inorganic Chemicals
MA	Marine Pollution
MM	Mining & Ore Processing
NR	Northern & Rural Regions
PF	Paper and Fibres
PG	Power Generation
PN	Petroleum and Natural Gas
SF	Surface Finishing
SP	Oil & Chemical Spills
SRM	Standard Reference Methods
TS	Transportation Systems
UP	Urban Pollution

New subject areas and codes are introduced as they become necessary. A list of EPS reports may be obtained from Environmental Protection Publications, Conservation and Protection, Environment Canada, Ottawa, Ontario, Canada, K1A OH3.

ENVIRONMENTAL STATUS REPORT FOR THE CANADIAN PETROLEUM REFINING INDUSTRY 1983-1984

by

Marie-Louise Geadah
Industrial Programs Branch
Environmental Protection
Conservation and Protection
Environment Canada

Report EPS 1/PN/1
December, 1987

READERS COMMENTS

Readers who wish to comment on the contents of this report should address their comments to:

Marie-Louise Geadah
Industrial Programs Branch
Environmental Protection Directorate
Conservation and Protection
Environment Canada
Ottawa, Ontario
K1A 0H3

Pour obtenir un exemplaire en français, prière de s'adresser à:

Publications de Protection de l'environnement
Conservation et Protection
Environnement Canada
Ottawa (Ontario)
K1A 0H3

Cat. No. En 49-11/1-1E
ISBN 0-662-15561-0
BEAUREGARD PRESS LIMITED

ABSTRACT

This report provides an overview of the Canadian petroleum refining industry with respect to gaseous, liquid, and solid waste releases; pollution control methods; and waste disposal practices. Federal and provincial air quality, effluent and solid waste requirements are presented. An assessment of the state of compliance of the industry with the Federal Petroleum Refinery Effluent Regulations and Guidelines for the years 1983 and 1984 is also provided. In 1983, Canadian refineries were, on average, in compliance with the monthly amounts and stormwater limits more than 92% of the time, and more than 97% of the time with the daily limits. The performance improved slightly in 1984.

Other recent environmental studies pertaining to the industry are discussed including studies on: trace contaminants in effluents, analytical methodology for the effluents, groundwater contamination, and decommissioning.

RÉSUMÉ

Le présent rapport porte sur l'industrie du raffinage du pétrole au Canada, et plus particulièrement sur ses rejets de résidus gazeux, liquides et solides, ses méthodes de dépollution et ses pratiques d'élimination des déchets. Le cas échéant, les exigences fédérales et provinciales en matière de qualité de l'air, d'effluents et de déchets solides sont présentées. Le rapport contient également une évaluation du degré de conformité de l'industrie aux règlement et directives fédéraux sur les effluents des raffineries de pétrole, pour les années 1983 et 1984. En 1983, les raffineries canadiennes ont respecté les quantités mensuelles imposées et les limites sur les rejets dans les eaux pluviales plus de 92 p. 100 du temps et les limites quotidiennes plus de 97 p. 100 du temps. La performance de l'industrie s'est améliorée légèrement en 1984.

D'autres études environnementales récentes concernant cette industrie font également l'objet d'un examen, dont: les polluants à l'état de traces dans les effluents; les méthodes d'analyse des effluents; la contamination des eaux souterraines; la désaffectation d'usines de raffinage et les mesures qui s'y rattachent.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The author wishes to thank the Petroleum Association for Conservation of the Canadian Environment, the company personnel and Environment Canada regional personnel for their cooperation in providing information and for their review and constructive comments on the draft report.

Acknowledgements are also extended to Art Stelzig, Head of the Oil, Gas and New Fuels Section for reviewing and commenting on the report and for providing general guidance and support during preparation; to the two students Michael Way and Wayne Dejong for their contribution in the compliance assessment section; and to all the others who reviewed the draft. Special thanks are also due to Vicky Jones and particularly Stella Wheatley for critically editing the original document and suggesting improvements; to the translation personnel for preparing the French version of the report; the French editing unit and particularly Michèle Létienne-Prévost; and to the word processing personnel for their efforts in typing and making the revisions.

GLOSSARY

Activated carbon	Carbon that is specially treated to produce a very large surface area that is used to adsorb undesirable substances.
Actual deposits	The amount of contaminants discharged in refinery effluents.
Adsorption	Attraction exerted by the surface of a solid for a liquid, or a gas when they are in contact.
Aerobic bacteria	Bacteria that require free oxygen to metabolize nutrients.
Air blowing	Refers to the process used to produce asphalt by reacting residual oil with air at moderately elevated temperatures.
Altered refinery	An altered refinery is an existing refinery in which the primary crude oil atmospheric distillation tower was replaced (after October 31, 1973).
Anti-icing additive	A fuel additive used to minimize ice formation.
Antiknock compound	Chemical compounds such as tetraethyllead and aromatic hydrocarbons, that are added to motor and aviation gasolines to improve their performance and to reduce knock in spark-ignition engines.
Anti-oxidants	Chemicals added to products such as gasoline and lubricating oil to inhibit oxidation.
APHA	American Public Health Association.
API	American Petroleum Institute.
Authorized deposits	The amount of contaminant that is authorized by the federal regulations and guidelines, to be discharged in the effluent of a refinery.
Bioaccumulate	Accumulate in the food chain.
Biodegradation	Process whereby a substance is decomposed by micro-organisms.
Blowdown	Removal of liquid from a refinery vessel (storage or process) through the use of pressure.
BOD	Biochemical Oxygen Demand. The amount of dissolved oxygen required by aerobic microorganisms to biodegrade organic matters contained in wastewater. The BOD test is used to measure the organic content of wastewater and surface water.
BOD_5	Test procedure for measuring BOD for 5 days at 20°C.

Bottom sludge	Heavy material, usually composed of oil, water and impurities, which collects in the bottom of storage tanks or vessels.
BPT	Best Practicable Treatment Technology.
BTEX	Benzene, Toluene, Ethylbenzene and Xylene.
BTX	Benzene, Toluene, Xylene.
Carcinogenic	Cancer-producing agent.
Catalyst	A substance which alters the velocity of a chemical reaction without itself being altered.
CO Boiler	The carbon monoxide waste-heat boiler is used to recuperate the heat of combustion of carbon monoxide and other combustible (mainly hydrocarbons). The feed is oxidized producing carbon dioxide and water.
COD	Chemical Oxygen Demand. The amount of oxygen equivalent of the organic matter required to complete chemical oxidation in an acidic medium. The COD test is used to measure the organic content of wastewater and natural water.
Cone-roof tank	A type of hydrocarbon-storage tank with a roof in the form of a flat inverted cone to provide vapour space for filling operations.
Cooling tower	A large structure (usually wooden) in which atmospheric air is circulated to cool water by evaporation.
Cyclone	Device for particulate control, whereby particles (larger than 10 μm) are separated from the carrier gas through centrifugal force.
Daily limits	Refers to the limits of One-day amount and of Maximum daily amount in the federal regulations and guidelines.
DEA	Diethanolamine.
Dispersion	Scattering of particles (liquid or solid) under certain forces, that leads to a non-uniform distribution.
Electrostatic precipitator	A device which removes fine particles such as dust, fumes and mists from flue gases. The particles are first exposed to a high-voltage electric field and then attracted to highly charged collecting plates.
Existing refinery	A refinery that started operation prior to Nov. 1, 1973.
Expanded refinery	An existing refinery which has declared a revised reference crude rate that is more than 115% of the initial reference crude rate.

FCCU	Fluid Catalytic Cracking Unit.
FGD	Flue Gas Desulphurization.
Flares	Devices used to burn unwanted gas through a pipe or stack.
Floating-roof tank	An oil storage tank with a flat roof that floats on the surface of the oil reducing evaporation losses to a minimum.
Flue gas	Residual gas with low heating value produced from the combustion of fuel.
Fractionator	A cylindrical refining vessel where liquid feedstocks are separated into various components or fractions (e.g., distillation).
GVRD	Greater Vancouver Regional District.
Heat value	The heat liberated by the combustion of a unit quantity of a fuel.
Landfarm	An area where petroleum processing wastes are applied to the upper soil layers (i.e., landspread) so that soil microorganisms degrade the organic matter in the waste.
Landfill	A location where solid waste is buried in layers of earth in the ground for disposal.
Leachate	A solution resulting from the dissolving of soluble material from soil or solid waste by the action of percolating water or rainfall.
Liquid-liquid extraction	The process where two immiscible liquids are in contact to allow for the soluble material in the carrier liquid to be extracted in the solvent.
LPG	Liquefied Petroleum Gas.
Maximum daily amounts	A limit set in the federal regulations and guidelines for a number of parameters. This limit should not be exceeded on any day of the month in the refinery effluent.
MEA	Monoethanolamine.
Mercaptans	A group of organosulphur compounds having the general formula R-SH where "R" is a hydrocarbon radical such as CH_3 and C_2H_5. Mercaptans have strong, repulsive, garlic-like odours and are found in crude oil.
Metabolite	A final or intermediary product of physical and chemical processes that are carried out by an organism. These processes include the degradation of complex organic compounds and the synthesis of complex substances for use by an organism.

Molecular sieve	A synthetic zeolite mineral with pores that is capable of separating molecules on the basis of their size and/or structure. Molecular sieves are used in refineries to remove traces of water from jet fuel and for separating certain mixture of hydrocarbons.
Monthly amounts	A limit set in the federal regulations and guidelines for a number of parameters. This limit represents the amount that should not be exceeded on a daily average basis over each month in the refinery effluent.
Mutagenic	An agent that produces an abrupt change in the genetic material of an organism.
New refinery	A refinery that has not commenced the processing of crude oil prior to November 1, 1973.
NGL	Natural Gas Liquids.
96-hour flow-through bioassay	A test procedure required by the federal guidelines to evaluate the acute lethal toxicity of refinery effluent to fish. The procedure consists of exposing fish to a continually renewed effluent under controlled conditions over a 96-hour period. The percent mortality of fish is observed after the four-day period.
96-hour static bioassay	A test procedure similar to the 96-hour flow-through method but where the effluent is not renewed during the period of test.
Octane	A number indicating the relative antiknock value of a gasoline. The higher the octane number, the greater the antiknock quality.
Once-through cooling water	Water that has been circulated once through heat exchangers in order to remove heat from process streams without coming into contact with the stream.
One-day amounts	A limit set in the federal regulations and guidelines for a number of parameters in refinery effluents. Each refinery is allowed to exceed this limit only once during a month.
Ozonation	Water treatment method used to remove micropollutants (i.e., chemical pollutants present in small concentrations that are difficult to remove) or to disinfect water through the use of ozone as oxidant.
PACE	Petroleum Association for Conservation of the Canadian Environment.
PAH	Polynuclear Aromatic Hydrocarbons.

Photosynthetic action	A process by which organic compounds (mainly carbohydrates) are synthesized by chlorophyll-containing plant cells. The reaction takes place in the presence of light, carbon dioxide and water.
Phytotoxicological Substance	A substance toxic to plants.
Poly gasoline	A product of polymerization of normally gaseous hydrocarbons to form high-octane liquid hydrocarbons boiling in the gasoline range. Also called polymer gasoline.
Priority pollutants	A list of 129 toxic pollutants having known or suspected adverse effects upon human health or the environment. The U.S. EPA established this list and has the mandate to control these pollutants in wastewater discharged to the environment, under the Clean Water Act.
Reference Crude Rate (RCR)	The quantity of crude oil (expressed in 1000 m^3/d) declared by a refinery and that is used to calculate the authorized deposits. The reference crude rate is based on the actual crude oil rate processed by a refinery.
Residual pitch	A black, heavy residue produced in asphalt processing.
Sour water	Water containing impurities, mainly hydrogen sulphide or other sulphur compounds that make it extremely harmful.
Stripping	The removal of the more volatile components from a mixture. Generally, the process consists of passing the hot liquid from a flash drum or tower into a stripping vessel through which open steam or inert gas is passed to remove the more volatile components of the liquid.
TOD	Total Oxygen Demand. Amount of oxygen required to oxidize organic substances and, to a minor extent, inorganic substances in a platinum-catalyst combustion chamber. The TOD test is another method used to measure the organic content of wastewater.
24-hour static bioassay	A test procedure similar to the 96-hour static method but where the percent mortality of fish is observed after a 24-hour period.
U.S. EPA	The United States Environmental Protection Agency.
Volatilization	The conversion of a chemical substance from a liquid or solid state to a gaseous state by the application of heat and/or pressure. Also known as vaporization.

Zeolite catalyst	A catalyst that contains any of the various hydrous silicates (e.g., hydrated aluminum and calcium (or sodium) silicates) used in catalytic cracking units.

SUMMARY

This report provides an overview of the Canadian petroleum refining industry; and a comprehensive review of its gaseous, liquid (including wastewater) and solid wastes, and its pollution control methods and waste disposal practices. In addition, an assessment of the state of compliance of the industry with the Federal Petroleum Refinery Effluent Regulations and Guidelines for the years 1983 and 1984 is provided. Federal and provincial air quality, effluent and solid waste requirements are identified and discussed. Other recent environmental studies pertaining to the industry are also presented, including studies on: trace contaminants in effluents, analytical methodology for the effluents, groundwater contamination, and decommissioning.

The 1983 atmospheric emission estimates for the 28 operating refineries were based on a survey developed by the Petroleum Association for Conservation of the Canadian Environment (PACE) and Environment Canada. The 1983 annual emissions in Canada for the five common contaminants were as follows: 72 240 tonnes of carbon monoxide, mainly from catalytic cracking units (96%); 131 550 tonnes of sulphur dioxide, mainly from process heaters and boilers (51%) and catalytic cracking units (20%); 19 500 tonnes of hydrocarbons, 86% originating from storage tanks and 13% from pumps and compressors (loading facilities not included); 22 770 tonnes of nitrogen oxides (expressed as nitrogen dioxide), mainly from fuel combustion (78%); and 9 570 tonnes of particulate matter, from catalytic cracking units (56%) and fuel combustion (44%). Twenty of the twenty-four refineries having catalytic cracking units control carbon monoxide emissions by using carbon monoxide boilers. Seventy-one percent of the refineries have sulphur recovery systems, most using the Claus process (either two- or three-stage) and 14% have additional tail gas units. The floating-roof tanks (emit considerably less hydrocarbons than the cone roof) are replacing the cone-roof type which now represent only 11% of the total storage capacity. Particulate emissions from catalytic cracking units are controlled in 24 refineries by using internal cyclones (two- or three-stage). In addition, two of these refineries also use electrostatic precipitators.

Petroleum refineries were assessed for compliance with the federal regulations and guidelines for effluent discharge. Of the 36 refineries operating during all or part of 1983, five were subject to the regulations and the remaining were subject to the guidelines. Two refineries were not assessed because one had no discharge during the year, and the other (subject to the regulations) used deep-well injection for disposal of all its effluent. Of the remaining 34 refineries, 12 were in compliance with all the limits

more than 99% of the time, and five were in compliance between 95% and 99% of the time. Among the remaining 17 refineries, five had further treatment provided off-site, five improved their performance in 1984, and three others were decommissioned. On a national basis, the refineries were in compliance, on average, with the monthly amounts and the stormwater limits more than 92% of the time, and with the daily limits more than 97% of the time. In general, the regulations and guidelines limits were exceeded when the wastewater treatment systems were under upset conditions or suffered from mechanical deficiencies. Once the problems had been identified, corrective measures were taken to improve the quality of the effluent.

In 1983, eight refineries were shut down permanently leaving 30 refineries in operation in 1984 (one came on stream). The refinery performance generally improved in 1984; 56% of the refineries were in compliance at least 95% of the time as compared to 53% in 1983.

Of the four refineries that were subject to the regulations in 1983, two were in compliance 100% of the time, one was in compliance more than 98% of the time, and one, more than 89% of the time. In 1984, the performance improved, four were in compliance 100% of the time and one was in compliance more than 98% of the time.

From 1972 to 1983, there was a general downward trend for the net discharges (expressed in kg/d) of all the regulated parameters. The discharge level of sulphide reached an all-time low in 1980 followed by a 26% increase in 1983. Except for this parameter, all others were reduced during this period: oil and grease was reduced by 35%; total suspended solids by 29%; phenols by 53% and ammonia nitrogen by 21%. These reductions were not only caused by the 20% drop in production, but by the industry's continuous effort to meet and exceed federal and provincial requirements. This was achieved by the upgrading and replacement of existing facilities, and by the installation of efficient treatment systems at new refineries.

On average, 28% of the tests requested to be done by the regulations and guidelines were not reported in 1983. This is primarily because some refineries addressed only the provincial or municipal monitoring and reporting requirements which in some cases are different from the federal requirements.

Most of the refineries (81%) use a secondary treatment system to treat their effluent. The majority of these refineries have secondary treatment on-site, the others treat their effluent with a primary or intermediate treatment on-site first and then send their effluent to an off-site facility (usually a municipal treatment plant) for secondary treatment. Under good operating conditions, the existing treatment systems can easily meet the limits prescribed by the federal regulations and guidelines. Often levels are reached that are well below the limits. Environment Canada and PACE have commissioned a number of studies to characterize refinery wastewaters and assess the effectiveness of existing treatment systems in reducing the concentrations of trace contaminants (22, 23, 24). The major conclusion drawn from these studies is that a well-operated wastewater treatment system which uses "best practicable treatment technology" (used by most refineries) is very efficient in removing organic priority pollutants from refinery wastewaters, while most metals will be concentrated in the sludges. Eighty percent of the compounds from the U.S. Environmental Protection Agency's Priority Pollutants list were not routinely detected in refinery wastewaters. The priority substances consistently detected in the effluent were: chromium, zinc, benzene, naphthalenes, phenols, phthalates, polynuclear aromatic hydrocarbons, and some related compounds. The concentrations, in most cases, were below the water quality criteria published by the various regulatory agencies. It should be noted, however, that the effluent samples analyzed were taken at the refinery outfalls which are normally diluted (by a factor of approximately 10) with once-through cooling water.

In an attempt to update the analytical procedures that are required under the federal regulations and guidelines (13th edition APHA*), a study was conducted to compare the analytical results that would be obtained using the 13th and 15th editions of the APHA methods, for the regulated parameters. Analytical problems (results were not reproducible) were encountered when using the 15th edition method to analyze for oil and grease, phenols and ammonia nitrogen, suggesting the need for further refinement of the methods. Using 15th edition methodology produces higher results for phenols and ammonia nitrogen, although the differences were quite variable ranging from 0 to 120%.

From a 1978 PACE survey with 38 operating refineries responding, the total waste produced was estimated to be 196 kt/yr. Of this total, 61.8 kt/yr (on a dry basis) was solid or semi-solid waste, and 69 kt/yr was aqueous waste (mainly acid and caustic solutions). General refuse-type waste constituted 46% of the solid and semi-solid wastes. The disposal practices used for the total waste generated were: landfilling, 35.7%; recovery/recycling, 29.7%; landspreading, 17.8%; incineration, 6.9%; deep-well injection, 1.4%; and other methods, 8.5%. There was an indication that the use of landspreading is increasing. A recent laboratory study on landspreading of refinery waste indicates that there is a potential for biodegrading recalcitrant polynuclear aromatic hydrocarbons

---

* APHA, Standard Methods for the Examination of Water and Wastewater, 13th edition, American Public Health Association (1971).

(found in the waste) through appropriate and controlled land application (21). Another study is underway to confirm these laboratory results in the field. Further studies will still be required, however, to determine the optimum operating measures.

Other studies were conducted to determine the fate of dissolved hydrocarbons that enter the groundwater through spills on the refinery site, or leaks from underground storage tanks (25, 26). The most soluble components of gasoline (benzene, toluene, xylene, known as BTX) were studied because they represent the greatest environmental concern. Based on laboratory work, biodegradation of BTX in groundwater can be achieved by the naturally occurring aerobic microorganisms with the addition of oxygen or nitrate. This experiment is presently being verified in the field.

A total of 14 refineries have shut down their plants over the past ten years (1976 to 1986). Several of them are undergoing decommissioning which involves the dismantling of equipment and preparation of the site for future use. A number of activities should be carried out to identify environmental concerns and to clean up decommissioned sites including: a plant site contamination assessment prior to field sampling; sampling of soil, groundwater, and surface waters; identification of cleanup criteria; site cleanup; confirmatory analyses to ensure that the cleanup was effective; and a long-term monitoring program (if required). Existing refineries can apply preventive measures to reduce the cost and complexity of eventual site cleanup. These measures include: proper waste management; monitoring of soil and groundwater to detect potential contamination and cleanup before problems develop; and keeping detailed records on environmental practices. For new refineries, decommissioning factors such as the ability of the proposed plant site to degrade, neutralize or contain contaminants from plant operations can be considered at the site selection stage. Design, operating, and waste management practices are features that can be built into a new facility to prevent or contain losses. Regular environmental auditing of all internal operations and procedures that may have environmental implications is a growing practice in this industry and reflects a proactive and progressive approach to sound environmental management.

1 INTRODUCTION

In November 1973, Environment Canada issued the Petroleum Refinery Effluent Regulations and Guidelines (1) under the Federal Fisheries Act (2). The regulations and guidelines do not apply to facilities associated with the production of synthetic petroleum from coal or bituminous sands. Status reports on the industry's compliance with the regulations and guidelines have been published by Environment Canada for 1975, 1977 and 1980. These documents, however, were limited to the assessment of liquid effluents. This report, in addition, provides an overview of the industry and all the wastes generated by its operations (gaseous, liquid and solid). For the first time, refineries are identified by name and location, consistent with the department's policy on "information availability" which was announced in 1982, to comply with the Access to Information Act (3).

Estimates of air emissions and solid wastes were based on industry surveys performed by the Petroleum Association for Conservation of the Canadian Environment (PACE) and/or by Environment Canada. The compliance assessment is based on reports prepared by the regional offices of Environment Canada in cooperation with industry and the respective provincial environmental agencies. Environment Canada and the provincial agencies periodically audit refinery effluents through field surveys. A number of environmental studies that were commissioned by PACE and/or Environment Canada over the past few years are discussed in this report. These include studies on: the fate of PAH* when disposed of on land (landspreading); trace contaminants in oil refinery effluents; analytical procedures required by the regulations and guidelines for refinery effluents; the fate of dissolved organics in groundwater; and the environmental aspects of decommissioning industrial sites. A discussion of federal and provincial regulatory requirements and current pollution abatement technologies is also presented.

For the purpose of this report, Canada was divided into five regions: the Atlantic region (including Newfoundland, New Brunswick, Nova Scotia and Prince Edward Island); the Ontario region (just the province of Ontario); the Quebec region (just the province of Quebec); the Western & Northern region (including Manitoba, Saskatchewan, Alberta and the Northwest Territories); and the Pacific & Yukon region (including British Columbia and the Yukon Territory). The assessment of the industry's compliance with the regulations and guidelines was made on a national, regional, and individual refinery basis.

---

*PAH: polynuclear aromatic hydrocarbons

2 DESCRIPTION OF THE PETROLEUM REFINING INDUSTRY

In 1983, there were 36 petroleum refineries operating in Canada with a total crude throughput of approximately 256 000 m^3/d. The refineries in Ontario and Quebec were processing 58% of the total crude, while the large production area of the Western & Northern region (mostly Alberta) was processing 22%. Eight refineries were permanently shut down during 1983 and two new refineries started operating (one in 1983 and one in 1984). The national production of 30 refineries was reduced to 251 000 m^3/d in 1984. Ontario still had the highest production (32%), and the Western & Northern region had the same production as Quebec (24%).

The primary function of a petroleum refinery is to separate crude oil and convert it into products such as: gasoline, diesel fuel oil, heavy and light fuel oils, petrochemical feedstock, aviation fuels, asphalt, LPG (liquefied petroleum gas), lubricants, kerosene, stove oil, and other products. Based on 1984 data, gasoline accounted for 39% (by volume) of the total production, followed by diesel fuel oil (18%) and heavy and light fuel oils (10% each).

Crude oil is the principal raw material for a petroleum refinery and may be of natural origin (from underground geologic formations) or synthetic (recovered from tar sands). Crude oil is a mixture of many hydrocarbons and varies considerably in composition and physical properties depending on its source. The elementary composition usually falls within the following ranges: 84 to 87% carbon (by weight), 11 to 14% hydrogen, 0 to 3% sulphur, 0 to 1% nitrogen, 0 to 2% oxygen, 0 to 1% water and 0 to 0.1% mineral salts. In addition, the crude may contain trace amounts of heavy metals such as iron, arsenic, chromium and vanadium. Crude oils are broadly classified by hydrocarbon composition as: paraffinic (not prevalent in Canada), naphthenic, asphaltic, mixed (contains paraffin and asphaltic material), and aromatic base (prevalent in the Middle East).

2.1 General

The processes used to convert crude oil into various products can be divided into four major steps: **separation, conversion, treating** and **blending.** Crude oil is first separated into selected fractions mainly by distillation and to a lesser extent by solvent extraction and crystallization. Conversion processes are used to change the size and shape of the hydrocarbon molecules to give them more monetary value. These processes include: catalytic cracking (to break large molecules into smaller ones); catalytic reforming and isomerization (to rearrange molecules); and alkylation/polymerization (to join molecules together). Impurities (such as: sulphur, nitrogen and oxygen compounds) that end up in intermediate products are removed or modified by treating processes such as desulphurization, denitrification, or treatment with chemical (caustic or acid). As a final step, the refined products are usually blended and some additives are added to improve the quality of the products to meet finished product specifications. A simplified flow diagram of the various refinery processes and products is shown in Figure 1.

2.2 Industry Processes

2.2.1 Separation.

Atmospheric Distillation. In this process, the crude oil is first preheated, and mixed with water in a desalter. The water is then separated from the crude, taking with it the salts entrained in the oil from the geological formation. This desalted crude is then reheated and fed to the distillation column at slightly above atmospheric pressure. The crude is then separated, by distillation and steam stripping, into fractions of specific boiling temperature range. The various fractions are continuously drawn off and diverted for further processing or used as finished products. The lighter products are withdrawn from the top of the column; lower points on the tower draw off progressively heavier fractions. The tower bottoms, which contain the heaviest petroleum fraction, are transferred to the vacuum distillation tower for further separation.

Vacuum Distillation. In this process, the residue from the atmospheric distillation tower is separated under vacuum into a heavy residual pitch, one or more heavy gas oil streams, and residuals.

2.2.2 Conversion.

Cracking Processes. Typical cracking processes include catalytic cracking, hydrocracking, and visbreaking or coking (both thermal cracking processes).

a) Catalytic cracking is a key process in increasing the quality and quantity of gasoline fractions. The most commonly used is the fluid bed type. The process uses a finely powdered zeolite catalyst that is kept in suspension in the reactor by the incoming oil feed from the bottom of the reactor. The oil vaporizes upon contact with the hot catalyst and is cracked into smaller molecules. Vapours from the reactor are separated from the entrained catalyst and fed into the fractionator, where the desired products are removed and heavier fractions are returned to the reactor. The catalyst becomes deactivated by thermal degradation and by coming in contact with heavy metals in the feed, necessitating regeneration or replacement.

b) Hydrocracking is basically a catalytic cracking and a hydrogenation process. In this process polycyclic compounds are broken to produce single ring and paraffin-type

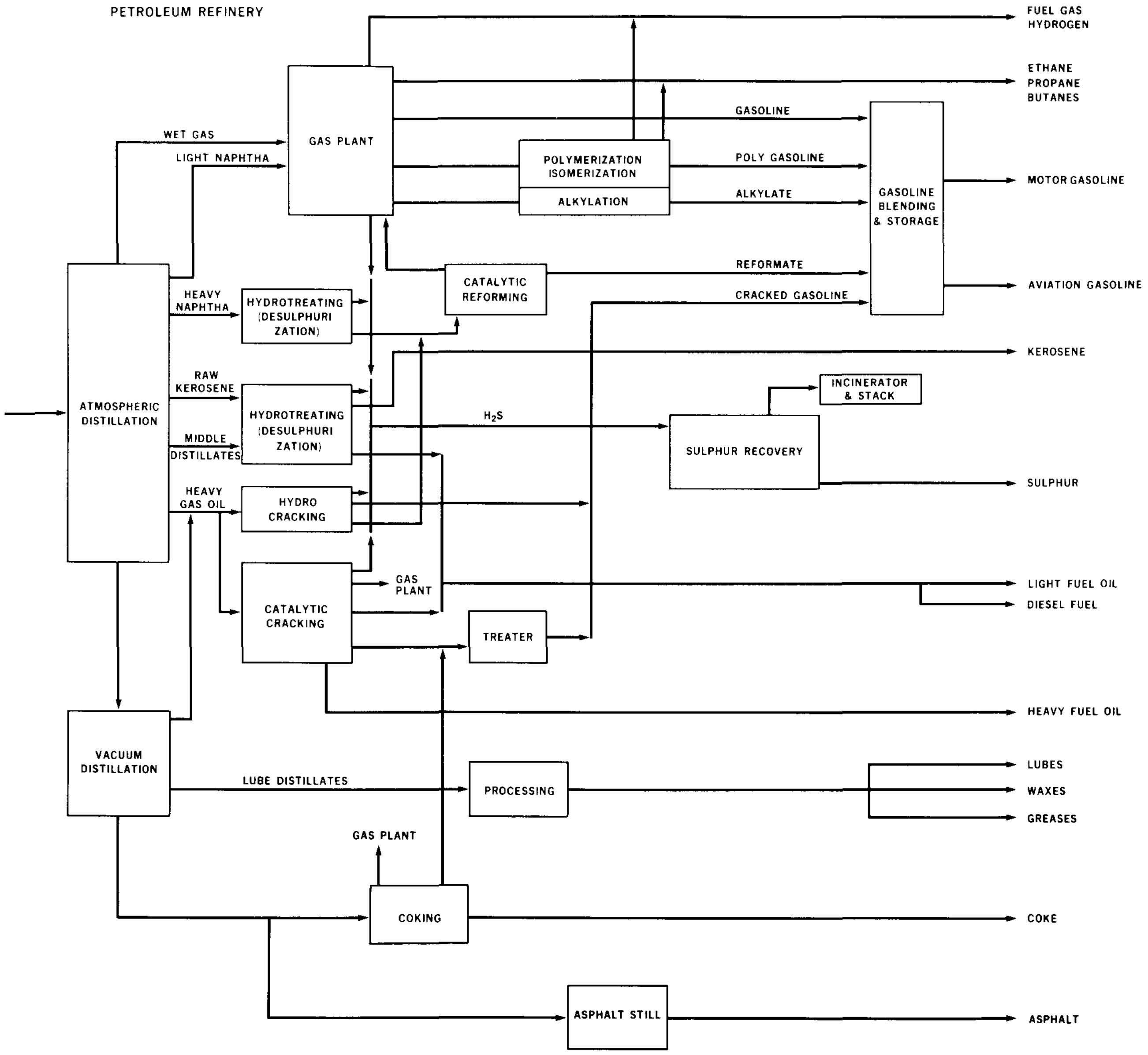


FIGURE 1 SIMPLIFIED PETROLEUM REFINERY PROCESS FLOW DIAGRAM

hydrocarbons. In addition, sulphur and nitrogen are removed producing hydrogen sulphide and ammonia. These reactions occur at high temperatures and pressures in the presence of hydrogen and a catalyst.

c) Visbreaking is an old process that was replaced by catalytic cracking and hydrocracking. Visbreaking is a mild thermal cracking operation designed to reduce the viscosity of the charge stock. The feed is heated and thermally cracked in the furnace. Cracked products are delivered to a fractionator where the low boiling materials are separated into light distillate products, while the liquid is processed in another fractionator (may be at vacuum) to recover a heavy distillate, and the residue or tar may be used for coker feed or as plant fuel.

d) Coking processes (fluid or delayed) are used only by a few refineries in Canada. Coking is a severe thermal cracking process in which the feed is held at high cracking temperature and low pressure for coke to form and settle out. The cracked products are sent to a fractionator where gas, gasoline and gas oil are separated and drawn off, and the heavier material is returned to the coker.

Rearranging Processes. The most widely used rearranging process is catalytic reforming which improves the octane quality of gasoline from crude oil. This is achieved by molecular rearrangement of naphthenes through dehydrogenation and of paraffins through isomerization and dehydrocyclization. The reformer catalyst, commonly platinum chloride on an alumina base, may also contain an activity-increasing noble metal such as rhenium. In many units the catalyst is regenerated or replaced every 6 to 12 months. In other units, the catalyst is withdrawn continuously and regenerated on-site for further use. Refineries are choosing more and more continuous reformers which do not require periodic shutdown for catalyst regeneration as do conventional reformers. The dehydrogenation and dehydrocyclization reactions produce large quantities of hydrogen as a by-product that can be used for various hydrogen treating processes.

Combining Processes. Two processes, alkylation and polymerization, are used to produce gasoline blending stocks from the gaseous hydrocarbons formed during cracking operations.

a) Alkylation is the reaction of an olefin with an iso-paraffin (usually isobutane) in the presence of a catalyst (either 98% sulphuric acid or 75 to 90% hydrofluoric acid) to produce high octane compounds known as alkylate. The reaction occurs under controlled temperatures and pressures. The reactor products are separated in a settler where the acid is returned to the reactor and the alkylate is further processed. This hydrocarbon stream is scrubbed with caustic to remove acid and organically combined sulphur, before going to the fractionation section. Isobutane is recirculated to the reactor feed, the alkylate is drawn off from the bottom of the debutanizer and the normal butane and propane are removed from the process and used as LPG. The alkylate, normal butane and propane products are also scrubbed with caustic soda.

b) Polymerization is a reaction which joins two or more olefin molecules. This process has been declining in use since both yield and quality of gasoline product are inferior to those of the alkylation process. The feed must be treated first with caustic soda to remove sulphur compounds and then with water to remove nitrogen compounds and excess caustic soda. These treatments are required to protect the catalyst in the reactor. After treatment, the hydrocarbon feed is contacted with an acid catalyst in the reactor under high temperature and pressure. The catalyst is usually phosphoric acid or in some older units sulphuric acid. The polymerized product from the reactor is then treated to remove traces of acid.

2.2.3 Treating.

Hydrotreating. Hydrotreating is a relatively mild hydrogenation which saturates olefins and/or reduces sulphur, nitrogen, and oxygen compounds along with halides and trace metals present in the feed, without changing the boiling range of the feed. This process stabilizes the product by converting olefins and gum-forming unstable diolefins to paraffins and also improves the product's odour and colour. Although there are various types of hydrotreating units, each has essentially the same process flow. The feed is combined with recycled hydrogen, heated to the reaction temperature, and charged to the reactor. In the presence of a catalyst (metal-sulphide), the hydrogen reacts with the oil to form hydrogen sulphide, ammonia, saturated hydrocarbons, and free metals. The metals remain on the catalyst and other products leave the reactor with the oil-hydrogen stream. The reactor products are cooled and then put into a hydrogen separator, from which hydrogen is returned to the system. The oil is sent to a fractionator for separation of light naphtha and hydrogen sulphide from the desirable feedstock.

Chemical Treating. A number of chemical methods are used throughout the refinery to treat hydrocarbon streams. They can be classified into three groups: acid treatment, sweetening processes, and solvent extraction.

a) Acid treatment consists of contacting the hydrocarbons with concentrated sulphuric acid to remove sulphur and nitrogen compounds, to precipitate asphaltic or gum-like materials, and to improve colour and odour.

b) Sweetening processes oxidize mercaptans to less odoriferous disulphides without the actual removal of sulphur. The most common sweetening processes are the Merox processes; others include the lead sulphide, the hypochloride, and the copper chloride processes. In the Merox process, a catalyst composed of iron group metal chelates is used in an alkaline environment to promote the oxidation of mercaptans to disulphides using air as a source of oxygen.

c) Solvent extraction involves the use of a solvent that has an affinity for the undesirable compounds and is easily separated from the product. Mercaptans are extracted using a strong caustic solution. The solvent is usually regenerated by heat, steam stripping or air blowing.

Gas Treating. These processes are used to remove the sulphur compounds from the various gaseous streams. Hydrogen sulphide (H_2S) can be extracted by an amine solution to produce a concentrated stream of H_2S that can be sent to a sulphur recovery plant.

Treatment by Physical Means. Physical methods are intermediate steps in crude processing operations and are often used to treat hydrocarbon streams or remove undesirable components. These methods include electrical coalescence, filtration, adsorption and air blowing. Physical methods are applied in desalting crude oil, wax removal, decolorizing lube oils, brightening diesel oil (to remove turbidity caused by moisture), and others.

2.2.4 Blending and Additives. *A number of intermediate streams called "base* stocks" are blended to produce a product that will meet various specifications. Typical requirements may include specific volatility, viscosity, octane and other parameters. The blending operation involves the accurate proportioning of the base stocks along with proper mixing, to produce a homogeneous product.

To improve the properties of the products, a number of additives are used. Tetraethyllead, for example, is added to gasoline to increase the octane number although, with the recent regulation that limits the quantity of lead in gasoline, other additives are being used to increase the octane of gasoline. Other additives used are anti-oxidants, anti-icing agents and metal deactivators to inhibit gum formation.

3 AIR EMISSIONS

3.1 Regulatory Requirements

The federal jurisdiction for atmospheric pollution is prescribed by the Clean Air Act (4). Under this Act, the federal government has the authority to: establish national ambient air quality objectives; formulate national emission guidelines for various sources (stationary, such as a petroleum refinery, or other sources); regulate the composition of fuels; and prescribe national emission standards for stationary sources where there is significant danger to health or where there are international agreements, or in the absence of these agreements, where there is reasonable cause to believe that the health, safety or welfare of persons in another country is endangered.

The provinces have established generic legislation to control atmospheric pollution. Only Quebec, Alberta and British Columbia have standards that are specific to petroleum refineries. In Quebec, the refineries located in the Montreal Urban Community (MUC) must comply with MUC by-laws (for air emissions) in addition to the provincial legislation.

3.1.1 Federal Requirements. Under the Clean Air Act, National Ambient Air Quality Objectives (5) have been established for sulphur dioxide, nitrogen dioxide, suspended particulate matter, carbon monoxide, and ozone. These are ambient air quality objectives which are not specific to the petroleum refining industry. The objectives describe three concentration ranges: tolerable, acceptable and desirable. The tolerable range indicates levels that require immediate abatement to avoid further deterioration to an air quality that would endanger the prevailing lifestyle or that would pose a substantial risk to public health. The acceptable range establishes levels within which adequate protection against adverse effects on personal comfort and well being, visibility, animals, vegetation, soil, water and materials may be provided. The desirable range is intended to provide a long-term goal for air quality and a basis for the protection of unpolluted parts of the country.

The composition of fuels is regulated under the Clean Air Act. The lead content in leaded motor gasoline, for example, has recently been regulated to reduce the level from 0.77 to 0.29 g/L. This new level came into effect January 1, 1987 (unleaded motor gasoline remains at 0.013 g/L), and the federal government intends to introduce legislation to phase out lead in gasoline by the end of 1992. In addition, petroleum refineries are required to report the sulphur content of their petroleum products and the fuel additives that are being used.

3.1.2 Provincial Requirements. Most provinces have established ambient air quality requirements that are equivalent to the Federal National Ambient Air Quality Objectives. Provincial requirements that are specific or that apply to the petroleum refining industry are discussed in the following.

Quebec. Quebec has specific emission standards that are applicable to petroleum refineries. Particulate matter and carbon monoxide emissions from coking and catalytic cracking units must not exceed levels shown in Table 1. Control measures to reduce vapours escaping from tanks storing hydrocarbons are also specified (Table 2). Tables 3 and 4 provide emission standards for particulate matter and nitrogen oxide from fossil fuel combustion, respectively.

The sulphur content of a fuel that is to be burned cannot exceed (by weight): 3.0% for heavy oil; 1.0% for intermediate oil; 0.5% for light oil; and 2.0% for coal. Moreover, since December 1, 1980 the sulphur content of heavy oil produced must not exceed 2.5% by weight. The standards for heavy oil and coal do not apply in cases where: a portion of the sulphur contained in the flue gases is recovered and combined with a raw material; or a portion of the sulphur contained in the flue gases is recovered. It should be noted that if heavy oil or coal is used simultaneously in the same establishment with another fuel that has a low sulphur content, the standard would be applied differently (i.e., based on the equivalent heat value of the other fuel).

As stated previously, the refineries in Montreal (Petro-Canada, Shell, and Esso and Gulf while they were in operation) are also subject to MUC by-law No. 44 (6) which imposes stricter limits for some contaminants. According to the by-law, the sulphur content (by weight) of a fuel that is to be burned cannot exceed: 1.25% for heavy oil; 1% for intermediate oil; 0.4% for light oil; and for coal, the sulphur content is based on the equivalent heat value of another fuel. The MUC has also reduced the emission limits for particulate matter from catalytic cracking and coking units to 100 mg/m^3 (compared to 115 mg/m^3 for the rest of the province). In addition, allowable levels of particulate matter emitted from existing fuel-burning equipment are: 60 mg/MJ when the heat input capacity of the fuel fired is less than 60MW; and 43 mg/MJ when the heat input capacity is greater than or equal to 60MW.

Alberta. In Alberta, all refineries must be licenced to operate under the Alberta Clean Air Act (7). Each licence contains terms, conditions and requirements

TABLE 1 EMISSION CONTROLS FOR CATALYTIC CRACKING AND COKING UNITS (Quebec)

Age of Catalytic Cracking and Coking Units	Emission Limits under Standard Conditions	
	Particulate Matter	Carbon Monoxide
New (from June 1, 1981)	115 mg/m^3 of undiluted gas	500 ppm on dry basis
Existing (before June 1, 1981)	-	1500 ppm on dry basis

TABLE 2 VAPOUR CONTROL MEASURES FOR HYDROCARBONS FROM STORAGE TANKS (Quebec)

Type of Tank	Capacity (m^3)	Vapour Pressure under Normal Conditions (kPa)	Control Measures
New (from July 1, 1983)	$\geq$ 250	10 to 75	- equipped with floating roof or equivalent
All	$\geq$ 250	> 75	- equipped with vapour recovery system or equivalent
All	$\geq$ 5	-	- equipped with submerged filling pipe
Above ground	$\leq$ 5	-	- equipped with pressure vacuum valve or pressurized

TABLE 3 ALLOWABLE PARTICULATE MATTER EMISSIONS FROM EXISTING FUEL-BURNING EQUIPMENT (Quebec)

		Emission Limits (Particulate Matter mg/MJ)	
Heat Input Capacity in Fuel as Fired (MW)	Type of Fuel	New Installation	Existing Installation
3 to 15	Gas or oil product	60	85
3 to 70	Coal	60	85
15	Gas or oil product	45	60
70	Coal	45	60

Note: These limits have been in effect since June 1, 1981.

TABLE 4 ALLOWABLE NITROGEN OXIDE EMISSIONS FROM NEW FUEL-BURNING EQUIPMENT (Quebec)

Heat Input Capacity as Fired (MW)	Type of Fuel	Fuel Emission Standards (ppm, dry basis at 3% O_2)
70	Coal	500
	Oil	250
	Gas	200
15 to 70	Coal	450
	Oil	325
	Gas	150

specific to that refinery. The air emission limits that apply to petroleum refineries in Alberta are: 0.2 kg/1000 kg (particulate/flue gas), from all sources; 0.66 t/1000 m^3 (sulphur dioxide/crude oil processed), from all sources; and 1000 ppm of carbon monoxide from fluid catalytic cracking unit. The emissions from hydrocarbon storage facilities should be controlled by either a floating roof or an equivalent vapour recovery system when tanks over 15 m in diameter are used. Products with vapour pressures over 86 kPa should be stored in pressurized vessels.

British Columbia. The B.C. Department of Lands, Forests and Water Resources (now called Ministry of Environment and Parks) produced a report in 1974 entitled "Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia" (8). This document recommends control objectives to be used for establishing emission levels and guidelines for ambient air quality. The pollution control objectives for petroleum refineries are summarized in Table 5.

3.2 Emission Sources and Control Measures

The major emission sources in the petroleum refining industry are: storage tanks, process heaters and boilers, catalytic cracking unit regenerators, and sulphur plants and sour water strippers. There are also other minor emission sources from: wastewater separators, blowdown facilities, loading facilities, relief valves, flares, and leaks from valves, flanges, pump and compressor seals. The most common contaminants emitted by refineries are: carbon monoxide, sulphur oxides, hydrocarbons, nitrogen oxides and particulate matter. In addition, lesser emissions of malodorous materials occur, including hydrogen sulphide (H_2S), mercaptans, aldehydes, ammonia, and phenolic compounds. The potential sources of each contaminant are summarized in Table 6.

3.2.1 Carbon Monoxide. Carbon monoxide is mainly generated from catalyst regeneration in the catalytic cracking unit and is discharged with the regenerator flue gases. To reduce the carbon monoxide emissions, the regeneration gases are either contacted with a promoter catalyst or sent to a carbon monoxide (CO) boiler to be oxidized to carbon dioxide and water. In most cases, auxiliary fuel is required in addition to the carbon monoxide in order to raise gases to ignition temperatures. The CO boiler also oxidizes the sulphur compounds in the fuel to sulphur dioxide and converts the small amounts of ammonia in the regeneration flue gas into nitrogen oxides. In Canada, most refineries use CO boilers.

3.2.2 Sulphur Dioxide. The main sources of sulphur dioxide (SO_2) emissions are:

1) the combustion of fuel oil or fuel gas;
2) catalytic cracking regenerator gas;
3) sour water stripper off gas (source of H_2S); and
4) the sulphur recovery unit.

TABLE 5 OBJECTIVES FOR PETROLEUM REFINERY AIR EMISSIONS (British Columbia)

	Level A	Level B	Level C
Sulphur Plant			
Sulphur Recovery, % (a)	99+	99	94
Sulphur Dioxide mg/m^3 (ppm)	830 (300)	(b)	(b)
Overall Refinery			
Sulphur Trioxide, mg/m^3	25	50	100
FCCU Regenerator			
Particulate Solids, mg/m^3	115	345	690
Hydrocarbons (as Hexane) mg/m^3 cracking feed, (ppm)	90 (25)	180 (50)	540 (150)
Carbon Monoxide, mg/m^3 (ppm)	2400 (2000)	2400 (2000)	120 000 (100 000)
Sulphur Dioxide, mg/m^3 (ppm)	830 (300)	1650 (600)	2800 (1000)
Steam Plant			
Particulate Solids, mg/m^3 (c)	150	200	300
Sulphur Dioxide, mg/m^3 (ppm)	830 (300)	1650 (600)	2800 (1000)

(a) total sulphur recovered from refinery fuel gases
(b) emission concentration objectives are not set for Levels B and C but must be such as to maintain ambient air quality guidelines
(c) corrected to 12% carbon dioxide

Level A: objectives for new and proposed discharges and, within the best practicable technology, to existing discharges by planned staged improvements for these operations

Level B: intermediate objective for all existing discharges to reach within a period of time specified by the Director, and as an immediate objective for existing discharges which may be increased in quantity or altered in quality as a result of process expansion or modification

Level C: immediate objective for all existing petroleum industries to reach within a minimum technically feasible period of time

TABLE 6 POTENTIAL EMISSION SOURCES FROM OIL REFINERIES

Contaminant Emitted	Potential Sources
Carbon Monoxide	- catalyst regeneration, decoking, compressor engines, incinerators
Sulphur Oxides	- boilers, process heaters, catalytic cracking unit regenerators, treating units, H_2S flares, decoking operations
Hydrocarbons	- loading facilities, turnarounds, sampling, storage tanks, wastewater separators, blowdown systems, catalyst regenerators, pumps, valves, blind changing, cooling towers, vacuum jets, air blowing, high pressure equipment handling volatile hydrocarbons, process heaters, boilers, compressor engines, barometric condensers
Nitrogen Oxides	- process heaters, boilers, compressor engines, catalyst regenerators, flares
Particulate Matter	- catalyst regenerators, boilers, process heaters, decoking operations, incinerators
Aldehydes	- catalyst regenerators
Ammonia	- catalyst regenerators, sour water strippers
Odours	- treating units (air-blowing, steam-blowing), drains, tank vents, barometric condenser sumps, waste-water separators, gas treating units (H_2S)

Sulphur compounds (originally in the crude oil) that are not transferred to the refinery flue gases, remain in the liquid and solid products. The highest concentration of sulphur is generally found in the heaviest liquids, which are from the vacuum tower bottoms. When these liquids are used as fuel for the refinery's own consumption, the sulphur is converted and released as sulphur dioxide. To reduce these emissions, the "heavy bottoms" can be desulphurized or blended with a low sulphur, light oil. At some refineries, vacuum tower bottoms are blended with light and heavy cycle gas oil to manufacture heavy fuel oil which is sold and used as liquid fuel within the refinery.

Process gas and fuel gases containing significant levels of hydrogen sulphide (H_2S) and organic sulphides are treated to remove the sulphur components. A lean amine solution is used to absorb the hydrogen sulphide from the fuel gas. The solution is later stripped of its hydrogen sulphide; the stripped overhead gas along with other flue gases is then sent to the sulphur recovery plant. The "Claus" process is used in most refineries to recover the sulphur from these gases. In this process, air is fed at a controlled rate to a furnace to oxidize one third of the hydrogen sulphide to produce some sulphur dioxide (SO_2). The exit gas is cooled to condense the elemental sulphur produced. The gas is then reheated and enters the catalytic converter where the hydrogen sulphide and the sulphur dioxide react to produce additional elemental sulphur. To increase the sulphur production, the catalytic conversion can be repeated after condensing the additional sulphur. The gas (tail gas) released from the last conversion stage of the Claus process is usually burned to produce sulphur dioxide. Some refineries use a tail gas cleanup system to further recover the sulphur from the tail gas and reduce the sulphur dioxide emissions.

Canadian refineries do not directly control sulphur dioxide emissions from catalytic cracking units apart from minimizing the sulphur content of the feedstock and selecting a catalyst that has less tendency to retain sulphur dioxide. The flue gas desulphurization (FGD) process could be applied to reduce the sulphur dioxide emissions. There are two types of FGD processes: nonregenerative and regenerative. The nonregenerative type removes sulphur dioxide from the flue gas and converts it to a non-marketable product that must be disposed of as a landfill material. The regenerative type removes sulphur dioxide and produces marketable forms of sulphur (elemental sulphur, pure sulphur dioxide, sulphuric acid, and gypsum).

3.2.3 Hydrocarbons. The major sources of hydrocarbon emissions are:

1) storage tanks;
2) flares, pumps, and compressors;
3) fuel combustion;
4) loading facilities; and
5) miscellaneous sources.

The volatility of the petroleum products or crude oils that are stored in tanks, is responsible for hydrocarbon vapour emissions. These emissions are a result of diurnal temperature changes, filling operations, and volatilization. Hydrocarbon losses from tanks can be effectively controlled by the use of a floating-roof tank instead of a cone roof or by connecting a vapour recovery system to the vents of a cone roof. In Canada, the floating-roof tanks, which are becoming more prevalent, accounted for 89% of the total storage capacity in 1983.

Pumps and compressors emit significant amounts of hydrocarbons. Mechanical seals of the single or double type are more effective than the packing type in reducing leakage between the pump shaft and the atmosphere. In Canada, mechanical seals are replacing the packing type. To reduce hydrocarbon emissions from pumps and compressors, they should be vented to a disposal system for recovery or to a flare. In addition, appropriate devices are available to ensure smokeless burning of hydrocarbons that are released through flares.

The filling of vessels used to transport petroleum products can be a significant source of hydrocarbon emissions. When the product is loaded, it displaces gases containing hydrocarbons to the atmosphere. To minimize these losses, the vapours can be collected by enclosing the filling hatch and directing the captured vapours to a recovery or disposal system. Another method being used to minimize losses is submerged loading.

Miscellaneous hydrocarbon emission sources include: mechanical leaks, vacuum jet and barometric condensers, cooling towers, wastewater separators, engine exhaust, venting and purging during turnaround, and air blowing. Emissions from these sources are generally minor and intermittent. To minimize these emissions, closed systems with vapour recovery and/or complete combustion could be used prior to atmospheric release. Hydrocarbon emissions from water separators could be covered to reduce evaporation of the skimmed oil.

3.2.4 Nitrogen Oxides. These emissions are mainly from fuel combustion and from the catalytic cracking unit. During the combustion of fuel, nitrogen oxides (NO_X) are formed in the boiler from the oxidation of nitrogen contained in the air and in the fuel. Factors that affect nitrogen oxides formation include the combustion chamber design and temperature, the amount of excess air present, and the amount of nitrogen in the fuel itself. The most effective measure for controlling nitrogen oxides emissions is to minimize their formation through modified combustion techniques. This includes controlling operational parameters and changing furnace design for new facilities.

3.2.5 Particulate Matter. Two major sources of particulate matter emissions are the catalyst in regenerator gas from the catalytic cracking units, and fuel combustion (particularly heavy fuel oil) at process heaters and boilers.

Catalyst particulate can escape along with the flue gases from the regenerator of the catalytic cracking unit. The recovery of these emissions is achieved by passing the gases through multi-stage cyclones and by electrostatic precipitators. The coarser particles are separated from the gas stream in the cyclone under the influence of centrifugal force. In the second or third stage cyclone, further separation takes place and finer particles (up to 10 μm) are removed. The electrostatic precipitator is used to remove particles that are smaller than 10 μm. The electrical conductivity of the particles in the gas stream may be increased by injecting ammonia.

Particulate is also formed during fuel combustion (particularly heavy fuel oil) in boilers, heaters, incinerators and flares. Proper design and operation coupled with electrostatic precipitators of the flue gas can provide adequate control. Smokeless flare systems and conversion of the fuel used in boilers and heaters to natural gas can also reduce particulate emissions.

3.2.6 Odours. Odorous emissions are relatively small compared to the total emissions. Miscellaneous emission of sulphur compounds such as mercaptans and hydrogen sulphide can be minimized by good design, and operation and maintenance practices. Waste gas containing hydrogen sulphide or ammonia can be directed to the sulphur recovery plant. However, the quantity of ammonia that can be directed to the Claus process is limited (since ammonia deactivates the catalyst used); ammonia can be separated from the hydrogen sulphide stream and then burned. Ammonia in wastewaters is generally reduced in the sour water stripping process. Hydrocarbon control systems such as floating-roof tanks and vapour recovery systems will reduce odours from storage tanks. Odours from air blowing may require special treatment systems.

3.3 Atmospheric Emissions

A questionnaire was developed in cooperation with the Petroleum Association for Conservation of the Canadian Environment (PACE) early in 1984 to determine the 1983 atmospheric emissions from the petroleum refining industry. The results are summarized in the following on a regional basis and include the emissions of the 28 refineries that were in operation for the entire year (1983). A more detailed analysis is provided in the PACE report (9).

3.3.1 Carbon Monoxide. Carbon monoxide emissions from catalytic cracking and the refineries' own fuel combustion are presented in Table 7. In 1983, carbon monoxide emissions from catalytic cracking units were estimated at 69 230 tonnes (96% of the total emissions) and 3009 tonnes were emitted through fuel combustion. Of the 24 refineries with catalytic cracking units, 20 controlled carbon monoxide emissions by using CO boilers.

TABLE 7 CARBON MONOXIDE EMISSIONS FROM CATALYTIC CRACKING AND FUEL COMBUSTION (1983)

Region	Catalytic Cracking Fresh Feed (m^3/d)[a]	CO Emissions (kg/d)[a]		
		Catalytic Cracking	Fuel Combustion from Own Consumption	Total
Atlantic	6 232.5	474.8	447.9	922.7
Quebec	11 283.4	1 233.6*	2 164.9	3 398.5
Ontario	18 412.8	84 362.5***	3 589.3	87 951.8
Western & Northern	15 044.3**	56 324.5***	1 475.7	57 800.2
Pacific & Yukon	6 832.2	47 276.2*	566.6	47 842.8
Canada (kg/d)[a]	57 805.2	189 671.6	8 244.4	197 916.0
(tonnes/year)	-	69 230.1	3 009.2	72 239.3
% of Total	-	95.8	4.2	100

* data not available for 2 refineries
** data not available for 3 refineries
*** data not available for 4 refineries
a - calendar day

3.3.2 Sulphur Dioxide. Sulphur dioxide emissions by source are presented in Table 8. The total emissions in 1983 were 131 550 tonnes. Fuel combustion in process heaters and boilers contributed to 51% of the total, catalytic cracking units accounted for 20%, sour water strippers for 13%, tail gas from sulphur recovery plants for 10%, and other sources, such as vents and flares, for 6%. Twenty refineries in Canada had sulphur recovery plants either on-site or utilize a plant off-site. Only one refinery uses the Stretford process the others use equally the two-stage and the three-stage Claus process. Six refineries use a tail-gas recovery system in addition to the Claus process (two- or three-stage).

3.3.3 Hydrocarbons. Emissions of hydrocarbons from storage tanks, pumps and compressors, and the refineries' own fuel combustion are presented in Table 9. Most of the 19 513 tonnes that were emitted in 1983 were from storage tanks (86%). Pumps and compressors accounted for 13%, and fuel combustion for 1%. Hydrocarbon emissions from loading facilities were not included in the estimate; however, splash loading has been

TABLE 8 SULPHUR DIOXIDE EMISSIONS BY SOURCE (1983)

Region	Crude Oil Charged in 1983 (m^3/d)**	SO_2 Emissions (kg/d)**									Total SO_2 Emissions (tonnes/yr)
		Process Heaters		Boilers		Catalytic Crackers	Sulphur Plants Tail Gas	Flares Vents Off-gas	Sour Water Strippers	Total	
		Gas	Oil	Gas	Oil						
Atlantic	41 948	6 875	2 986	3 410	9 374	9 519	8 559	1 671	9 115	51 509	18 801
Quebec	43 849	1 612	17 420	509	27 434	15 604	329	1 609	3 683	68 200	24 892
Ontario	77 619	2 063	32 561	960	38 289 (21 863) (coke)	22 495	20 829	3 661	28 634	171 355	62 545
Western & Northern	49 079	15 850*	0	697	2 365	16 649	3 101	5 930	1 894	46 486	16 967
Pacific & Yukon	22 036	692	118	176	74	6 652	2 247	10 681	2 230	22 870	8 345
Canada	234 531	27 092	53 085	5 752	99 399	70 919	35 065	23 552	45 556	360 420	131 550
% Total		7.5	14.7	1.6	27.7	19.7	9.7	6.5	12.6	100	

* 91% due to one refinery
** calendar day

TABLE 9 HYDROCARBON EMISSIONS FROM STORAGE TANKS, FUEL COMBUSTION, PUMPS, AND COMPRESSORS AT REFINERIES (1983)

	Hydrocarbon Emissions (tonnes/yr)			
Region	Storage Tanks	Fuel Combustion from Own Consumption	Pumps/ Compressors	Total Emissions
Atlantic	3 096.9	19.7	504.8	3 621.4
Quebec	6 078.8	57.4	437.3	6 573.5
Ontario	1 849.9	89.3	724.8**	2 664.0
Western & Northern	3 710.8	48.2	586.6	4 345.6
Pacific & Yukon	2 013.9	17.5	277.6*	2 309
Canada	16 750.3	232.1	2 531.1	19 513.5
% of Total	85.8	1.2	13.0	100.0

* data not available for 1 refinery
** data not available for 2 refineries

almost eliminated and replaced by submerged loading to reduce vapour losses. In addition, newer installations use bottom loading, which further reduces the emissions. In 1983, 529 floating-roof tanks were in service, which represented 89% of the total storage capacity. In addition, 184 cone-roof tanks were in service.

3.3.4 Nitrogen Oxides. Nitrogen oxides, expressed as nitrogen dioxide (NO_2), emissions from catalytic cracking and fuel combustion are shown in Table 10. The nitrogen oxide contribution from fuel combustion was 17 763 tonnes (78% of the total emissions) and 5005 tonnes from catalytic cracking units.

3.3.5 Particulate Matter. Emissions of particulate from catalytic cracking units and fuel combustion are presented in Table 11. The estimated emissions from catalytic cracking units were 5319 tonnes while gaseous and liquid fuel combustion accounted for 4253 tonnes. Most refineries used cyclones to control particulate emission from catalytic cracking unit regenerator gas. In 1983, 19 refineries used two-stage internal cyclones and among these two used additional electrostatic precipitators, while six used a one-stage external cyclone in addition to the two-stage system.

TABLE 10 NITROGEN OXIDE EMISSIONS FROM CATALYTIC CRACKING AND FUEL COMBUSTION (1983)

Region	Catalytic Cracking Fresh Feed (m^3/d)***	NO_2 Emissions (kg/d)*** Catalytic Cracking	Fuel Combustion	Total
Atlantic	6 232.0	1 272.0	3 914.0	5 186.0
Quebec	11 283.0	2 210.0	14 164.0	16 374.0
Ontario	18 413.0**	4 714.0**	22 160.0	26 874.0
Western & Northern	15 044.0*	4 331.0*	6 113.0	10 444.0
Pacific & Yukon	6 832.0	1 185.0	2 314.0	3 499.0
Canada				
(kg/d)***	57 804.0	13 712.0	48 665.0	62 377.0
(tonnes/yr)		5 005.0	17 763.0	22 768.0
% of Total		22.0	78.0	100.0

Note: nitrogen oxide emissions are expressed as NO_2
* missing data from 3 refineries
** missing data from 1 refinery
*** calendar day

TABLE 11 PARTICULATE EMISSIONS FROM FUEL COMBUSTION AND CATALYTIC CRACKING (1983)

Region	Particulate Matter Emissions (tonnes/yr) Catalytic Cracking Unit	Fuel Combustion	Total
Atlantic	315.4	203.6	519.0
Quebec	1 527.8	1 190.6	2 718.4
Ontario	1 675.0	2 747.1	4 422.1
Western & Northern	1 314.3	86.9	1 401.2
Pacific & Yukon	486.7	24.6	511.3
Canada	5 319.2	4 252.8	9 572.0
% Total	55.6	44.4	100

4 EFFLUENT DISCHARGE

4.1 Regulatory Requirements

In order to protect fish and marine organisms, the Federal Fisheries Act prohibits the deposit of deleterious substances in waters frequented by fish. To this end, the Petroleum Refinery Effluent Regulations and Guidelines were issued on November 1, 1973.

The provinces of Quebec, Ontario, Alberta, and British Columbia have objectives, guidelines or regulations to supplement the federal legislation. In other provinces, effluent control is based on the federal regulations and guidelines or on general industrial requirements.

4.1.1 Federal Limits. The Canadian Petroleum Refinery Effluent Regulations apply to "new" refineries (i.e., those that came on stream on or after November 1, 1973). The guidelines apply in general to "existing" (i.e., those refineries in operation prior to this date). Regulations have the force of law, whereas guidelines are statements of practice considered to be in compliance with the "spirit of the law". Failure to comply with the guidelines is not in itself an offence but it may mean that the Fisheries Act is being transgressed.

The regulations and guidelines limit the deposits of oil and grease, phenols, sulphide, ammonia nitrogen, total suspended matter (solids) and the pH levels. Furthermore, the regulations and guidelines specify monitoring methods and reporting frequency. Limits as set in the regulations are usually more stringent than those in the guidelines except for pH levels which are the same for both. In addition, the guidelines set an acute fish toxicity limit which applies to both "existing" and "new" refineries. The intent of the regulations and guidelines is to apply a national baseline standard uniformly across Canada; however, more stringent standards may be imposed by provincial or local governments depending on local circumstances. The purpose of the federal regulations and guidelines is to ensure that all refineries in Canada apply the best practicable treatment technology (BPT) to their liquid effluents.

Effluent limitations. The limits shown in Table 12 represent the maximum allowable deposits for all parameters. The limits for oil and grease, phenols, sulphide, ammonia nitrogen and total suspended matter represent the maximum net values (i.e., the amount contributed by the refinery) excluding background concentrations in the refinery intake water. In addition, the allowable deposits expressed in $lb/10^3\ bbl{\cdot}d^{-1}$

TABLE 12 AMOUNTS TO BE USED FOR CALCULATING MAXIMUM ALLOWABLE DEPOSITS OF SUBSTANCES (1)

	Monthly Amount $\text{lb}/10^3\ \text{bbl}\cdot\text{d}^{-1}$ $(\text{kg}/10^3\ \text{m}^3\cdot\text{d}^{-1})$ of crude oil		One-day Amount $\text{lb}/10^3\ \text{bbl}\cdot\text{d}^{-1}$ $(\text{kg}/10^3\ \text{m}^3\cdot\text{d}^{-1})$ of crude oil		Maximum Daily Amount $\text{lb}/10^3\ \text{bbl}\cdot\text{d}^{-1}$ $(\text{kg}/10^3\ \text{m}^3\cdot\text{d}^{-1})$ of crude oil	
Substance	Guidelines	Regulations	Guidelines	Regulations	Guidelines	Regulations
Oil and Grease	6.0 (17.1)	3.0 (8.6)	11.0 (31.4)	5.5 (15.7)	15.0 (42.8)	7.5 (21.4)
Total Suspended Matter	14.4 (41.1)	7.2 (20.5)	24.0 (68.5)	12.0 (34.2)	30.0 (85.6)	15.0 (42.8)
Phenols	0.6 (1.7)	0.3 (0.9)	1.1 (3.1)	0.55 (1.6)	1.5 (4.3)	0.75 (2.1)
Sulphide	0.2 (0.6)	0.1 (0.3)	0.6 (1.7)	0.3 (0.9)	1.0 (2.9)	0.5 (1.4)
Ammonia Nitrogen	5.0 (14.3)	3.6 (10.3)	8.0 (22.8)	5.7 (16.3)	10.0 (28.5)	7.2 (20.5)
pH					6.0 to 9.5	
Toxicity					No more than 50% fish mortality	

Note: The regulation and guideline limits are in imperial units only; metric units in brackets have been rounded (1, Schedule I).

$(\text{kg}/10^3\ \text{m}^3\cdot\text{d}^{-1})$ of crude oil, are based on the refinery maximum design stream day crude rate which is referred to as "Reference Crude Rate" (RCR). To assess compliance, the combined actual deposits of the contaminants measured in the liquid effluent and the once-through cooling water are compared with the allowable deposits shown in Table 12.

There are three levels of allowable limits for each substance deposited per day (kg/day). The first and lowest limit is the "Monthly Amount" which represents the amount that is not to be exceeded on a daily average basis in each month. The next highest is the "One-day Amount" limit. During a month, the refinery may deposit during a single day, a substance in excess of this limit only once. An unallowable discharge is recorded for each additional day in which the deposit exceeds this limit. The third and highest allowance is the "Maximum Daily Amount"; it is a limit that should not be exceeded on any day of the month. Deposits in excess of the monthly limit (particularly if repeated) are considered to be the most severe as they may indicate an ongoing problem.

The liquid effluent and the once-through cooling water should not at any time have a pH value outside the allowable range. Fish mortality should not exceed 50% in liquid effluent and in once-through cooling water.

Monitoring requirements. Each refinery is requested to test each of the five substances three times per week (Monday, Wednesday, and Friday) and to record the amount being deposited on those days. In addition, the pH level is to be measured daily. Refineries that are subject to the regulations must report the results of these tests. All refineries are requested to perform one toxicity test each month. The results of all analyses are to be reported monthly.

Some refineries may have obtained an exemption from normal monitoring and reporting requirements as a result of approved off-site treatment of their effluent or under particular circumstances.

Stormwater. Stormwater is runoff resulting from precipitation (rain, snow, etc.) that falls on the refinery site or that originates outside the refinery but passes over or through the refinery site, and is contaminated by any of the five parameters listed in Table 12. If clean (not contaminated) runoff is segregated, it is exempted from the regulations and guidelines. In addition to the authorized deposits listed in Table 12, further deposits of oil and grease, phenols and total suspended matter are allowed for days that a refinery is discharging stormwater. These additional limits are listed in Table 13.

Reference crude rate. As previously discussed, the reference crude rate (RCR) is needed to calculate the allowable deposits and should therefore be reported by the refinery for each month. If the actual crude throughput deviates from the RCR by more than 15%, a revised RCR may be declared by the refinery and used to calculate the authorized deposits.

Refinery status. Each refinery operates under a declared status (new, existing, expanded or altered) which indicates whether a refinery falls under the regulations or the guidelines. New refineries must meet the more stringent limits and are subject to the regulations. An existing refinery is always subject to the guidelines. An existing refinery also may have an expanded or altered status. A refinery is considered "expanded" when the declared RCR is greater than 115% of the initial RCR. The portion

TABLE 13 AMOUNTS TO BE USED IN CALCULATING ADDITIONAL DEPOSITS OF SUBSTANCES WHEN STORMWATER IS BEING DISCHARGED (1)

Substance	Allowance lb/10^4 gal.$\cdot d^{-1}$) ($kg/10^4$ L$\cdot d^{-1}$) of storm water	Maximum Allowance per month lb/10^3 bbl$\cdot d^{-1}$ ($kg/10^3$ $m^3 \cdot d^{-1}$) of crude oil	
		Guidelines	Regulations
Oil and Grease	1.0 (0.10)	50.0 (142.7)	25.0 (71.3)
Phenols	0.1 (0.010)	5.0 (14.3)	2.5 (7.1)
Total Suspended Matter	3.0 (0.30)	150.0 (428.0)	75.0 (214.0)

Note: The regulation and guideline limits are in imperial units only (1, Schedule II).

of the revised RCR that exceeds the initial RCR is subject to the more stringent allowable deposits equivalent to new refinery limits. The replacement of a crude tower is the indicator selected to determine whether or not a refinery has an "altered" status. The portion of the RCR represented by the new tower is subject to the more stringent allowable deposits equivalent to new refinery limits.

Off-site treatment. A refinery may be given an exemption from the requirements for liquid effluent and once-through cooling water if treatment is provided in facilities outside the refinery (such as municipal sewage systems). This exemption is only granted if the off-site facility provides treatment equivalent to that required by the regulations and guidelines.

Toxicity. The acute toxicity test requirement was included in the guidelines to serve as an indicator of the presence of other parameters that are not specifically controlled such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), and heavy metals. It applies to all the refineries (including new ones). The 24-hour static bioassay test should be performed by the refinery on both the liquid effluent and the once-through cooling water. The method is described in the guidelines. The 96-hour flow-through bioassay is also described and should be conducted periodically by Conservation and Protection, Environment Canada.

The guidelines are intended to limit the quantities of contaminants discharged. This will result in the reduction of volume of effluent discharged which produces a more concentrated effluent; this effluent is more likely to be toxic to fish. To encourage the reduction of contaminants discharged but not penalize refineries with low water consumption, a dilution of the refinery effluent is granted for those with a low water usage rate.

Analytical methodology. The regulations and guidelines also specify the test method to be used to analyze each parameter. The prescribed method is outlined in the American Public Health Association's Standard Methods for the Examination of Water and Wastewater, 13th ed. (1971) (10). If approved, an equivalent method could be used by the refinery provided the results can be confirmed by the APHA method.

4.1.2 **Provincial Limits.** Appendix A provides a summary of the federal and provincial limits for the common pollutants in refinery wastewaters.

Quebec. Refineries in Quebec are regulated by Liquid Effluent Guidelines under the Environmental Quality Act (11). Limits for the deposits are essentially the same as the federal ones. The main deviations from the federal regulations and guidelines are: in Quebec, the federal regulations' limits for stormwater apply to both new and existing refineries; and the fish toxicity test is not a requirement under Quebec's guidelines.

Ontario. Guidelines established by Ontario are generally consistent (depending on the volume of effluent discharged), with the national regulations and guidelines, although limits are expressed as concentrations. The Ontario effluent quality objectives shown in Table 14 may be superseded by site-specific requirements which are negotiated according to the sensitivity of the receiving water. These guidelines are being revised and more stringent standards for conventional pollutants and new standards for trace substances are expected.

Alberta. As in other provinces, Alberta refineries are subject to the federal regulations and guidelines as a minimum requirement. In Alberta, however, refineries that discharge their effluent into sensitive watercourses may be subject to more stringent standards which are included in the refinery permit and operating licence. The guidelines deposits for common contaminants are provided in Appendix A. Effluent objectives for toxic elements in refinery effluents are summarized in Table 15.

British Columbia. Recommended guidelines and minimum objectives for the control of water pollution from petroleum refineries are included in the "Report on

TABLE 14 EFFLUENT QUALITY OBJECTIVE FOR PETROLEUM REFINERIES (Ontario)

Substance	Maximum Concentration (mg/L)
Oil and Grease	10
Phenols	0.020
Suspended Solids	15
Ammonia Nitrogen	10
Chemical Oxygen Demand	200
Chromium	1
Copper	1
Nickel	1
Lead	1
Zinc	1
pH Levels	5.5 to 9.5
Toxicity	No more than 50% fish mortality for process effluent, once-through cooling water and treated stormwater.

TABLE 15 EFFLUENT OBJECTIVES FOR TOXIC ELEMENTS IN REFINERY WASTEWATER (Alberta)

Toxic Element	Net Concentrations (mg/L)*
Chromium (hexavalent)	0.30
Cyanide	0.025
Lead	0.10
Mercury	0.0005
Zinc	1.0
Nickel	1.0

* The net concentration value is calculated as:

$$\text{Net Concentration Value} = \frac{CF}{a}$$

where: C = the net concentration measured in effluent (mg/L).

F = the effluent flow rate (gal./min. per 1000 barrels of crude processed per day).

a = a constant, which defines nominal liquid effluent flow rates per 1000 barrels of crude processed per day as, 13.4 gal./min. for refineries with disposal wells, or 20 gal./min. for refineries without disposal wells.

Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia" (8). The objectives, as shown in Table 16, are divided into three levels:

Level A:	the objectives for discharges from new and proposed refineries and, within the limits of the best practicable technology, discharges from existing refineries through planned improvements;
Level B:	the intermediate objectives for discharges from all existing refineries, to be achieved within a period of time specified by the Director of the Pollution Control Branch, and for discharges from existing refineries that may be increased in quantity or altered in quality as a result of process expansion or modification; and
Level C:	the immediate objectives for all existing refineries, to be achieved within a minimum technically feasible period of time.

In general, the daily average limits are stricter than the federal monthly amounts. In addition to the common pollutants, British Columbia specifies a number of other parameters, including metals. The fish toxicity test required is the 96-hour static bioassay with 50% survival. The refinery effluent may be diluted to perform the bioassay test, and the level of dilution is set according to the refinery status (levels A, B, C, discharging into marine water or freshwater).

4.2 Wastewater Generation

Refinery wastewater contaminants originate from the following sources:

1) crude oil;
2) refinery intake water;
3) refinery stormwater;
4) ballast water;
5) sanitary wastes;
6) process chemicals and catalysts;
7) reaction products from conversion units; and
8) chemical additives.

Crude oil is a complex mixture of hydrocarbons, but also contains impurities. These are in the form of organic compounds of sulphur, nitrogen, oxygen, and a number of metals. In addition, inorganic salts are contained in crude oil in the form of emulsified brine. In order to minimize hydrochloric acid formation in the distillation tower, crude oil should be desalted, and in some cases, neutralized with caustic soda and ammonia. To reduce the salt, crude oil is contacted with water which is emulsified in the crude, and the mixture is passed through a chemical or electrostatic desalter. In the desalter, the oil phase is separated from the brine. The water phase will contain oil, desalting chemicals,

TABLE 16 EFFLUENT QUALITY OBJECTIVES FOR PETROLEUM REFINERIES (British Columbia)[(a)]

	Discharges to Marine Water			Discharges to Freshwater		
	Level A	Level B	Level C	Level A	Level B	Level C
Oil, nonvolatile, lb/1000 bbl. crude (mg/L)	--	2.80	(15)	--	2.80	(15)
Oil, total, lb/1000 bbl. crude	1.15(b)	--	--	0.58(b)	--	--
BOD, five-day, 20°C, lb/1000 bbl. crude	2.30(b)	8.0	8.0	2.30(b)	8.0	8.0
Phenols, lb/1000 bbl. crude	0.023	0.06	0.2	0.023	0.06	0.2
Sulphides and Mercaptans as S, lb/1000 bbl. crude (mg/L)	0.011	0.02	(1.0)	0.011	0.02	(1.0)
Ammonia, lb/1000 bbl. crude (mg/L)	0.576	1.87	(15)	0.576	1.87	(15)
Suspended solids, mg/L(c)	20	20	30	20	20	30
Settleable solids, mg/L	<0.5	<0.5	< 0.5	< 0.5	<0.5	<0.5
Floatable solids	(d)	(d)	(d)	(d)	(d)	(d)
Total solids, g/L	3.0(e)	3.0(e)	3.0(e)	1.5	1.5	2.0
Cyanide, mg/L	0.10	0.10	0.20	0.10	0.10	0.20
Chromium, total, mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Lead, total, mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Zinc, total, mg/L	0.2	0.2	0.3	0.2	0.2	0.2
Copper, total, mg/L	0.1	0.1	0.1	0.1	0.1	0.1
Nickel, total, mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Phosphate (as P), mg/L	3.0	3.0	3.0	1.0	1.0	3.0
Dissolved oxygen, mg/L	>1.0	>1.0	--	5.0	>1.0	>1.0
pH	6.5 to 8.5	6.5 to 9.0	6.5 to 9.0	6.5 to 8.5	6.5 to 8.5	6.5 to 9.0
Temperature, °F maximum	90	90	90	90	90	90
Turbidity, J.T.U.	15	15	25	10	10	15
Toxicity (f)	75	50	5	100	75	5
Process effluent volume (g) (Imp. gal$\cdot$min^{-1}/1000 bbl$\cdot$d^{-1})	8.0	13.0	--	8.0	13.0	--

(a) These objectives include process effluent and storm runoff from the processing area. Excluded are ballast water from ships, once-through cooling water used for indirect cooling, and storm runoff from dyked tank storage areas and undeveloped areas.

(b) These values are tentative and subject to review.

(c) Not applicable to discharges to exfiltration ponds.

(d) Negligible.

(e) Depends upon the nature of solids other than normal marine composition.

(f) 96-h TLm Static bioassay on salmonid species, expressed as percent by volume of effluent in receiving water which is required to give 50% survival over 96 hours.

(g) Normal dry weather flow (does not include storm runoff). Not a restrictive objective. If effluent volume discharged is greater, concentration must be reduced proportionately.

dissolved salts and suspended solids. Sour water, after stripping, is generally used as wash water in the desalter to reduce freshwater consumption.

Intake water will contain a variety of impurities depending on the refinery location (on river, ocean, upstream industry). The water will usually require treatment prior to being used in boilers and cooling towers. Water hardness and silica content will determine the degree of treatment and the quantity of blowdown from these systems.

Stormwater that falls on the refinery site collects silt and any spilled oil from refining processing and tank farm areas. Stormwater may also contain traces of phenols and other contaminants.

Ballast water is water which is carried in navigational vessels for stability and includes water used for cargo or ballast tank cleaning. Refineries that ship products by marine tanker receive the ballast water prior to loading the vessel. The water generally contains oil, phenols and trace amounts of suspended solids and total dissolved solids.

Sanitary wastes generated by personnel working in refinery office buildings, control rooms and laboratories are collected and either treated on-site or sent to the municipal sewer system. The contribution to the total refinery BOD and suspended solids from this source, however, is small.

Process chemicals and catalysts are used in a refinery and can lead to water contamination. Process chemicals may include caustic soda, sulphuric and phosphoric acids, amines, sulpholane, furfural, glycol, ammonia, detergents for chemical cleaning, process additives such as antifoam agents, corrosion inhibitors (chromium and zinc), lime and water softening chemicals for boiler feed water preparation, and nutrients for biotreater operation. In processes such as in the wet treating of products, some of these chemicals enter into the refinery sewer.

Catalysts are used to facilitate the conversion of hydrocarbons into more valuable forms. The major catalysts that can lead to water contamination are:

1) sulphuric acid that is used in alkylation (a source of sulphonates, sulphates, organic esters and sulphuric acids);
2) hydrofluoric acid used in alkylation (can produce fluorides);
3) phosphoric acid used in polymerization (produces phosphates and phosphoric acid); and
4) wet-treating catalysts (Merox, Mercapfining ...).

Reaction products from conversion units generate contaminants that end up in the refinery liquid effluent. These processes include: hydrotreating, thermal cracking/visbreaking, coking, catalytic cracking, hydrocracking and reforming. Table 17 summarizes the various water contaminants that can be generated by these processes.

TABLE 17 CONVERSION PROCESSING UNITS THAT GENERATE WATER CONTAMINANTS

Process	Water Contaminant
Hydrotreating	- hydrogen sulphide, ammonia
Thermal Cracking/Visbreaking	- ammonia, nitrogen compounds, hydrogen sulphide, mercaptans, naphthenic acids, organic acids
Catalytic Cracking	- phenols, hydrogen sulphide, carbon disulphide, disulphides, triophenes and carbonyl sulphides, ammonia, cyanides and cyanates
Reforming	- benzene, toluene, xylene can show up as COD in gasoline storage tank water drainings
Alkylation	- sulphates, alkyl sulphonates and hydrofluoric acid

Chemical additives are used in the products to enhance the quality and meet specifications. These can include: corrosion inhibitors, antiknock compounds, anti-icing compounds, and antioxidants. The additives may enter into the effluent water as a result of spills from chemical storage.

In summary, the major sources of water contamination are: crude desalter/crude distillation; sour condensates from hydrotreating and cracking units; boiler feed and cooling water blowdown; and process wash waters. The significant contaminants are: oil and grease, phenols, COD, sulphides, ammonia, and suspended and dissolved solids. Minor contaminants include: cyanides, fluorides, alkylsuphonates, chromates and heavy metals (iron, zinc, copper, lead, nickel).

4.3 Wastewater Treatment

As intended by the federal regulations and guidelines, most refineries in Canada apply best practicable treatment technology to their liquid effluents, or in some cases, a variation thereof. The best practicable treatment is described in the regulations and guidelines as:

a) sour water stripping for ammonia and sulphide removal;
b) primary separation (such as an API separator) followed by;
c) intermediate treatment (such as air flotation) followed by;
d) secondary treatment (such as biological treatment);
e) final effluent clarification if required; and
f) segregation and treatment of stormwater if required.

In addition, good housekeeping and maintenance, safe disposal of spent chemical and adequate facilities for ensuring smooth, continuous operation of treatment system are recommended for achieving an acceptable effluent.

Currently, 81% of the refineries in Canada treat their effluents with secondary or tertiary treatment systems. This figure includes refineries that have primary or intermediate treatment systems on-site but, in addition, send their effluents for further treatment (biological) to the municipal sewage system.

A brief description of the various unit processes used by the refineries for wastewater treatment follows. The efficiency of the various units in reducing the contaminants is shown in Table 18.

4.3.1 **Primary Treatment.** Primary treatment systems include: sulphide and ammonia stripping, gravity separation, liquid-liquid extraction, filtration and pH control.

Stripping of sour water is used to reduce sulphide, ammonia and, to a lesser degree, phenols collected from various refining processes. The stripping process consists of a trayed or packed tower supplied with 50 to 240 kg of steam for each cubic metre of sour water stripped. The stripped gases may be incinerated or fed to the sulphur recovery plant. In the latter case a two-stage stripping process may be required to reduce the ammonia content of the hydrogen sulphide stream. The removal of ammonia will reduce problems associated with the presence of ammonia in the feed gas of the Claus sulphur recovery unit.

Gravity separation systems remove free oil and suspended solids from wastewaters. The system may consist of a tank (such as the ballast water tank), a pond (as the storm water retention pond) or a lagoon equipped with oil skimmers. Most refineries use an American Petroleum Institute (API) separator; however, the tilted-plate separator is finding increased use. The API separator is a large basin which allows free oil to rise to the surface to be reclaimed, and solids to fall to the bottom for removal and disposal. Many important design parameters govern the effectiveness of the API separator,

TABLE 18 EXPECTED PERCENT REDUCTION THROUGH WASTE TREATMENT SYSTEMS (12)

Treatment Method	Oil	Phenol	pH	Total Sulphides	Ammonia Nitrogen	Filtered Suspended Solids	BOD_5	COD	TOD	Cyanides	Lead	Chromium	Toxicity
Foul Condensate Stripper	NA	10 to 30%	Increases 1 to 2 points	96 to 99.8%	69 to 96%	NA	NA	Reduced	Reduced	75 to 90%	NA	NA	
API Separator	60 to 99%	Reduced	NA	Reduced	NA	10 to 50%	5 to 35%	5 to 40%	5 to 40%	NA	Reduced	Reduced	NA
Crude Desalter	NA	70 to 90%	NA	NA	NA	NA	NA	NA	NA	NA	Reduced	NA	
Air Flotation and Flocculation	75 to 90% 50 to 90% (emulsified)	Reduced	Increases slightly	Reduced	Reduced	50 to 90%	10 to 60%	10 to 50%	10 to 50%	NA	NA	Reduced	NA
Sludge Beds	NA	NA	NA	NA	NA	90 to 99%	NA	NA	NA	NA	NA	NA	
Storm Retention Ponds	50 to 95%	Reduced	NA	NA	NA	80 to 99%	Reduced	Reduced	Reduced	NA	NA	NA	NA
Biological Unit	50 to 80% (emulsified)	97 to 99%	Reduced by 1 point	90 to 99%	Reduced	Increases	60 to 85%	30 to 70%	30 to 70%	65 to 99%	NA	NA	Reduced
High Rate Sand Filtration	70 to 80%	NA	NA	NA	NA	50 to 99%	Reduced	Reduced	Reduced	NA	NA	NA	
Ballast Water Tanks	60 to 99%	Reduced	NA	Reduced	NA	10 to 50%	Reduced	Reduced	Reduced	NA	Reduced	NA	NA
Activated Carbon or Ozonation	50 to 90% (emulsified)	80 to 99%	NA	80 to 99%	10 to 30%	NA	50 to 90%	50 to 90%		80 to 99%			Reduced

NA - Not available.

including: the water temperature; the density and size of oil droplets; and the type of solids in the water. The tilted-plate separator is made of several corrugated plates titled at a 45° angle. The wastewater flows between plates and oil droplets collect on the underside and rise to the top while solids settle on lower side of the plates and settle to the bottom.

The main application of liquid-liquid extraction in refineries is for the extraction of phenolic compounds from various condensate waters. The extraction takes place in a crude oil desalter where water (usually stripped sour water) is mixed with crude oil and heated in the crude desalter. The emulsion formed is broken by electrical or chemical (caustic soda addition) means. Since phenols have an affinity to the oil phase, they are extracted from the water phase; on the other hand, crude oil is cleared of the silt and chlorides.

High-rate sand filtration which operates under pressure, serves mainly as a polishing device and is capable of removing all suspended solids down to a few micrometres in size, limited amounts of colour agents and traces of oil.

The pH of refinery wastewater needs to be controlled because it would be detrimental to subsequent biological processes or receiving waters. In some cases, phosphoric acid or ammonia is added to control pH and at the same time to supply nutrients for subsequent biological treatment.

4.3.2 **Intermediate Treatment.** Intermediate treatment systems include: flotation, coagulation-precipitation, and equalization.

Flotation is used to further remove undissolved oil and suspended solids from API separator effluents prior to discharge or biological treatment. Other contaminants such as phenols, BOD, and sulphides will also be reduced to a certain extent. The process may either be dissolved air or induced air flotation. In dissolved air flotation, wastewater is kept under pressure (275 to 350 kPa) and compressed air is added so that the air will dissolve. The wastewater then passes through a pressure-reducing valve forming minute bubbles in the water. The bubbles attach themselves to the oil and suspended particles in the wastewater and rise to the surface as froth which is continuously skimmed for treatment or disposal. To improve the effectiveness of the flotation unit in removing oil emulsions, chemical flocculating agents are added. In the induced-air process, the air is introduced by specially designed agitators or diffusers and is dispersed through the wastewater.

Equalization ponds are generally used ahead of biological oxidation units to reduce fluctuations in flow rates and loadings, since biological processes are sensitive to shock loading.

4.3.3 Secondary Treatment. Secondary treatment systems are biological oxidation processes which include: activated sludge, trickling filters, waste stabilization ponds, and aerated lagoons. The purpose of these treatment systems is to remove phenols and reduce BOD (including biodegradable priority pollutants) in the wastewaters. This is achieved by bacteria which consume the organic material contained in the wastewater and convert it into carbon dioxide and water. Oxygen and nutrients are required, and new bacteria are produced continuously. The biological mass of bacteria is then separated from the treated wastewater by settling, and then recirculated to the incoming waste.

Activated sludge is an aerobic (in the presence of oxygen) biological treatment process in which microorganisms (in high concentrations) are suspended in wastewater within a holding tank. Oxygen is introduced by mechanical aerator or diffused air systems. The treated effluent then passes through a sedimentation tank before being discharged to the receiving water or in some cases to further treatment. The activated sludge is returned to the reaction tank or disposed of (usually by landspreading).

Trickling filters consist of a fixed growth of aerobic microorganisms contained in a porous bed, normally of broken rock or coarse aggregate. Bacteria grow on the surfaces of the bed media and remove organic material from the wastewater by adsorption, bioflocculation, and sedimentation. Oxygen is supplied for rapid metabolism of the removed organic matter. The effluent is then clarified in a sedimentation tank.

Waste stabilization ponds and aerated lagoons are large shallow ponds in which dilute concentrations of microorganisms are mixed with wastewater. Oxygen is supplied by surface diffusion, mechanical aeration units, or by the photosynthetic action of the algae present in the pond, and is consumed by bacteria in the aerobic degradation of organic matter. Unlike the activated sludge process, the effluent from the stabilization pond or aerated lagoon is not settled prior to discharge because of the low concentration of biological solids maintained in the system. In addition, the biological solids are not recirculated.

4.3.4 Tertiary Treatment. Tertiary systems are used only by few refineries in Canada. The primary purpose of tertiary treatment is to remove organic matter, taste and odour producing substances, and dissolved inorganic substances. Activated carbon, filtration and chemical oxidation (such as ozonation) can be used effectively to remove these materials.

4.4 Effluent Discharges and Compliance with the Federal Regulations and Guidelines

This section presents the status of compliance of petroleum refineries in Canada with respect to the Federal Petroleum Refinery Effluent Regulations and Guidelines. A detailed analysis has been made for the 1983 discharge data and a less detailed evaluation of the 1984 data is also presented. The information provided by the refineries was assessed and compiled into annual compliance reports by Environment Canada regional offices. This national report is a summary of the regional reports.

The following points should be taken into consideration before interpreting the results that are presented in this section or those shown in Appendix B.

1. The actual annual deposits found in Appendix B and presented in this section were calculated by taking the arithmetic mean of the monthly amounts discharged during the year. The monthly amounts vary considerably from one month to another; therefore, the annual average alone does not accurately reflect the situation. To provide a better appreciation of the annual deposit, its standard deviation expressed in percentage is also given in Appendix B. In interpreting the results, the deviation should be taken into consideration.
2. There is a great disparity between refineries in the number of tests reported. This is because the refineries do not submit all the tests required. In addition, some refineries have been given an exemption from the normal reporting requirements. This disparity greatly affects the assessment of the number of deposits in excess of the limits and has an impact on the accuracy of the monthly amounts which are the average of the reported daily deposits. The performance of each refinery is best assessed by comparing the percentages of time that the refineries were not in compliance. This value takes into account the number of tests reported and, therefore, provides a good basis for comparison (Appendix B).
3. The analytical test method prescribed in the regulations and guidelines for analyzing an effluent sample is the one described in the 13th edition of the APHA Standard Methods (10), or any proven equivalent method. Many refineries are now using the 14th and the 15th edition (13, 14), of the APHA method as per provincial requirements. The 15th edition may provide higher results than the 13th edition for some parameters. Since not all the refineries are using the same method, direct comparisons are very difficult.

4.4.1 National Assessment. In 1983, 36 refineries were operating in Canada. Twenty-five had an "existing" status and six an "expanded" status as defined in the guidelines. The other five refineries were new and subject to the regulations.

Three refineries have come on line since 1980: Turbo Resources--Balzac in 1982, Husky--Lloydminster in 1983, and Shell--Scotford in 1984; all are in Alberta.

Several refineries were shut down in 1983, including: Ultramar--Holyrood, Esso--Montreal, B.P.--Anjou, Shell--Oakville, Shell--Winnipeg, Gulf--Calgary, Gulf--Kamloops and the old Husky refinery in Lloydminster which was decommissioned during 1983. In addition, the Texaco refinery in Montreal was permanently shut down in 1982 and Texaco Edmonton in 1984. Thirty refineries were left in operation in 1984. Nineteen of them had an existing status, five were expanded refineries, and six were new and therefore came under the regulations.

In 1983 and 1984 eight refineries (in the Pacific & Yukon, and the Western & Northern regions) provided primary or intermediate treatment on-site, and further treatment (sometimes secondary) off-site; only two of them received an exemption from the guidelines. One refinery (the new Husky--Lloydminster) uses deep-well injection for disposing of all its treated effluent and is therefore not subject to the regulations and guidelines. One additional refinery (Shell--Bowden) did not have any discharge in 1983 and in 1984. Five refineries in Ontario and Quebec also treat the effluents of associated petrochemical plants (not subject to the refinery regulations and guidelines) and one refinery (in B.C.) treats the effluent of an associated natural gas plant.

On average, 72% of the tests requested in the regulations and guidelines were reported for 1983. Different provincial reporting requirements are responsible for this situation. Two regions which contributed to this low average were the Pacific & Yukon which reported only 25% of the tests and the Western & Northern region which reported 65%.

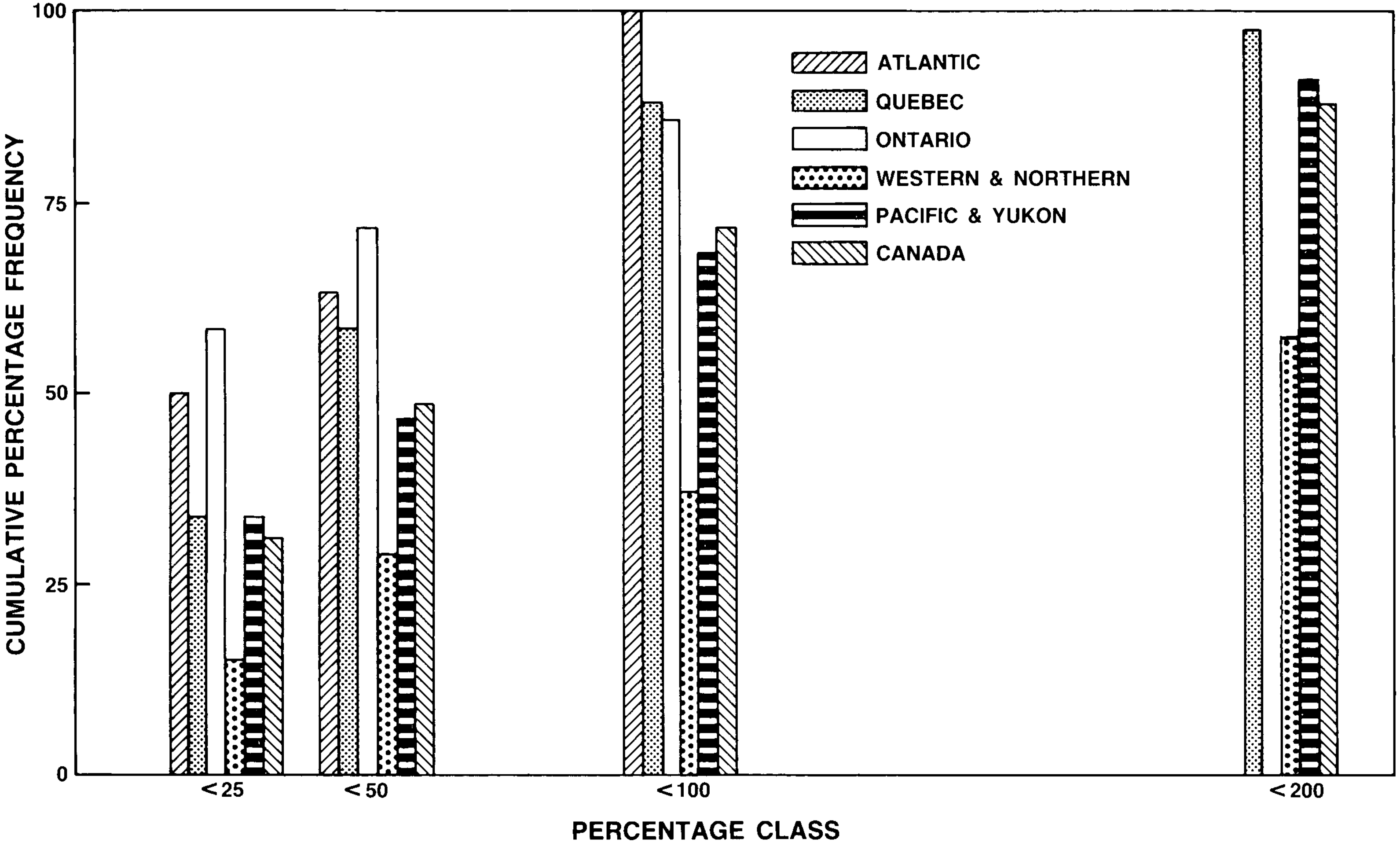
The performance in each region in 1983 is summarized in Appendix B. It should be noted that the authorized deposits apply only to individual refinery effluents. There is not an "authorized level", therefore, for a region, or for Canada. These calculated deposits, however, are useful in assessing the performance of the refineries as a whole within the various regions or within the country. Furthermore, the "authorized deposits" presented in the figures in this section and the tables in Appendix B were obtained by computing the yearly average of the authorized monthly amounts (calculated according to the regulations and guidelines). These authorized deposits are compared to the "actual deposits", which are a yearly average of the arithmetic monthly average of daily deposits. The refineries are not required to meet these yearly averages; they were calculated to provide an indication of the refineries' annual performance.

1983 National and Regional Performances. The overall national performance in 1983 was: in compliance 92% of the time with the monthly amounts, 98% with the one-day amounts, 97% with the maximum daily amounts, and 92% with the stormwater limits. Exceeding the monthly limits is considered more serious than exceeding the other limits. A regional breakdown of compliance with the monthly amounts of the guidelines by parameter is provided in Table 19. The Quebec region and the Western & Northern region exceeded the limits most frequently. The Ontario region had the best performance complying with the monthly amounts. The parameters of most concern for the refineries under the guidelines were oil and grease and total suspended solids. Sulphide limits were generally met most frequently by the refineries that are subject to the guidelines. Figure 2 provides an indication of the severity of the deposits that exceeded the limits of the monthly amounts. The y-axis represents the distribution of deposits (monthly average) that exceeded the monthly amounts; the x-axis indicates by how much these limits were exceeded. For Canada, 47% of the deposits that exceeded the monthly amounts were less than 50% above the limits and 17% were more than 200% above the limits. The majority of Ontario and Atlantic regions' deposits (57% and 50% each) that exceeded the limits were less than 24% above the limit. The Atlantic region did not have any deposits that were more than 100% above the limits. The Western & Northern region had the highest number of deposits (44%) that were more than 200% above the limits.

TABLE 19 PERCENT COMPLIANCE OF REFINERIES IN EACH REGION WITH MONTHLY AVERAGE LIMITS AS SET IN THE GUIDELINES (1983)

	% of Time in Compliance with the Guidelines					
Region	Oil and Grease	Total Suspended Solids	Phenols	Sulphide	Ammonia Nitrogen	Average
Atlantic	95	95	95	100	95	96
Quebec	52	66	90	98	87	79
Ontario	98	96	100	100	100	99
Western & Northern	89	88	91	92	85	89
Pacific & Yukon	96	97	91	96	95	95
Canada	86	88	93	97	92	92

Refinery Performance. Of the 34 refineries that were assessed in 1983 (excluding the refinery with deep-well injection and the one with no discharge), 12 refineries were in compliance with all the limits more than 99% of the time and five were in compliance between 95% and 99% of the time. Of the remaining 17 refineries, five had further treatment provided off-site, five improved their performance in 1984, and three others



Note: Cumulative Percentage Frequency = $\dfrac{\text{number of discharges that exceeded the limits by a specific \% class}}{\text{total number of discharges in excess of the limits}}$

Percentage Class = $\left[\dfrac{\text{discharge that exceeded the limit - limit}}{\text{limit}}\right] \times 100$

FIGURE 2 FREQUENCY DISTRIBUTION OF THE PERCENTAGE OF DISCHARGES IN EXCESS OF THE MONTHLY AMOUNTS LIMITS were decommissioned. The three refineries that had the lowest performance in relation to the monthly amounts were: the Co-op refinery in Regina (55% of the time in compliance); Esso--Norman-Wells (63%), and Shell--Montreal (69%). The Co-op effluent receives further treatment at the municipal treatment plant which, under normal conditions, would reduce the deposits to an acceptable level. It is suspected, however, that with levels as high as the 1983 and the 1984 deposits, the efficiency of the off-site treatment would be reduced. At Esso--Norman Wells, corrective measures were taken in 1984 to reduce the deposits. The Shell refinery in Montreal experienced some operating problems in its wastewater treatment system in 1983. The problems were corrected in 1984 although some improvements are still required. The overall performance of refineries in each region is provided in Table 20. A more detailed analysis of the performance of each refinery and each region is provided in the next section.

Trends in National Performance and Annual Deposits. The overall national compliance performance has been slowly improving since 1980. The percentage of time the nation was in compliance with the monthly amounts went from 91% in 1980, to 92% in 1983 and finally to 93% in 1984.

The national annual average of the deposits (expressed as kg/10^3 m^3 of crude oil) from 1972 to 1984 are presented in Figures 3 to 7. The downward trend for discharge levels continued in 1983 with improvements over the 1980 levels for oil and grease, total suspended solids, phenols and sulphide. Ammonia nitrogen levels remained unchanged for 1980 and 1983. In 1984, further reductions occurred for all parameters except phenols which remained the same as in 1983. Since 1980, all the annual deposits have been below the authorized levels. It should be noted that the negative value for the 1984 annual discharge of sulphide resulted from the calculation of net loading. In Ontario, the refineries' intake water contains a higher level of sulphide than the treated effluent, leading to a negative value when the refinery net loading is calculated.

Regional Comparison of 1983 Annual Deposits. The 1983 annual average of the deposits in each region is presented in Figure 8. The scale has been magnified for phenols and sulphide in Figures 9 and 10, respectively. Except for the oil and grease deposits in Quebec and the sulphide deposits in the Western & Northern region, all the annual deposits were below the authorized levels. The Quebec and the Atlantic region had the highest discharges of oil and grease and total suspended solids and the Western & Northern region had the lowest. The deposits of phenols are comparable in each region, although Ontario had the lowest. The largest contributor of sulphide is the Western & Northern region;

TABLE 20 OVERALL REFINERY PERFORMANCE WITH FEDERAL REGULATIONS AND GUIDELINES (1983-1984)

	1983 Performance					1984 Performance					
	% of Time in Compliance				% of Tests Reported	% of Time in Compliance				% of Tests Reported	
Refinery/Region	M	O	N	S		M	O	N	S		Comments*
Atlantic											
• Esso Petroleum (Dartmouth)	93.3	99.6	99.1	-	96	88	98.6	99.1	-	97	
• Irving (St. John)	96.7	99.9	96.4	-	80	93.3	99.2	98.6	-	82	
• Texaco (Dartmouth)	100	100	100	-	100	100	100	100	-	100	
• Ultramar (Holyrood)	95.8	98.7	99.5	-	70	-	-	-	-		shut down July 1983
• Region	95.8	99.7	98.8	-	90	94	-	-	-	93	
Quebec											
• Gulf (Montreal)	88.0	96.8	97.5	-	81	91.7	-	-	-		
• Esso Petroleum (Montreal)	78.0	98.6	97.4	-	87	-	-	-	-		shut down Oct. 1983
• B.P. (Anjou)	92.0	99.2	99.8	-	82	-	-	-	-		shut down May 1983
• Petro-Canada (Pointe-aux-Trembles)	73.0	96.1	97.4	-	96	65.5	93.0	97.0	-		
• Shell (Montreal)	69.0	93.3	94.5	-	100	88.3	-	-	-		
• Ultramar (St-Romuald)	78.0	92.7	89.0	-	95	95.0	-	-	-		
• Region	79.0	96.1	96.0	-	91	84.3	-	-	-		
Ontario											
• Esso (Sarnia)	100	99.9	99.7	-	100	95.0	99.0	98.6	-		
• Shell (Corunna)	95.0	99.9	98.5	-	71	90.0	97.5	96.5	-		
• Shell (Oakville)	100	100	100	-	82	-	-	-	-		shut down July 1983
• Petro-Canada (Oakville)	100	100	98.8	-	92	100	100	100	-		
• Gulf (Mississauga)	98.3	99.2	99.1	92.0	100	83.0	93.9	96.0	91.7		
• Suncor (Sarnia)	100	99.3	99.5	-	81	87.0	97.6	98.0	-		
• Petrosar (Corunna)	*100*	*100*	*99.9*	-	*84*	*100*	*100*	*100*	-		*subject to regulations*
• Texaco (Nanticoke)	100	100	99.9	100	100	100	100	99.9	100		subject to regulations
• Region	99.2	99.8	99.4	96.0	89	94.0	-	-	-	88	
Western & Northern											
• Gulf (Edmonton)	100	100	99.9	-	57	100	100	100	-	53	
• Gulf (Moose Jaw)**	92.0	-	-	-	6	100	-	-	-	6	
• Esso Petroleum (Norman Wells)	63.0	79.0	89.0	-	69	70	-	-	-	99	
• Shell (Bowden)	-	-	-	-		-	-	-	-		no discharge
• Shell (Winnipeg)	75.0	-	-	-	47	-	-	-	-		shut down Oct. 1983
• Texaco (Edmonton)	100	99.8	99.8	-	87	100	100	100	-		shut down May 1984
• Co-op (Regina)***	55.0	-	-	-	100	65	-	-	-		
• Gulf (Calgary)	100	100	99.9	-	68	-	-	-	-		shut down Dec. 1983
• Husky (Lloydminster)	-	-	-	-		-	-	-	-		deep-well injection;
• Esso Petroleum (Edmonton)	98.3	99.7	99.7	-	99	100	100	99.9	-		subject to regulations
• Turbo (Balzac)	89.0	100	99.9	-	60	98.3	100	100	-		subject to regulations
• Shell (Scotford)	-	-	-	-		100	-	-	-		subject to regulations
• Region	90.3	96.4	97.7	-	65	92.7	-	-	-		
Pacific & Yukon											
• Esso Petroleum (Ioco)	100	100	98.6	58.0	27	93.3	99.9	99	58.3		
• Gulf (Port Moody)	100	100	100	100	27	95.0	100	100	100		
• Gulf (Kamloops)	94.3	97.1	97.0	-	26	-	-	-	-		shut down May 1983
• Husky (Prince George)	100	100	96.4	-	24	100	100	99.9	-		
• Petro-Canada (Taylor)	88.0	98.4	98.3	97.2	27	97.9	100	100	94.4		
• Shell (Burnaby)	100	100	98.8	100	25	100	100	99.9	94.4		
• Chevron (North Burnaby)	83.0	97.5	92.0	100	22	90.0	100	-	97.9		
• Region	94.8	99.0	95.3	91.0	25	96.0	-	-	-		
National	92.4	97.7	97.2	92.4	72	92.8					

* Refineries were subject to the guidelines if not otherwise specified under Comments.
** Very few tests were reported (only 6%); performance is not representative.
*** Monthly amounts represent tri-monthly average.
M : *monthly amount; O : one-day amount; N : maximum daily amount; S : stormwater limits.*

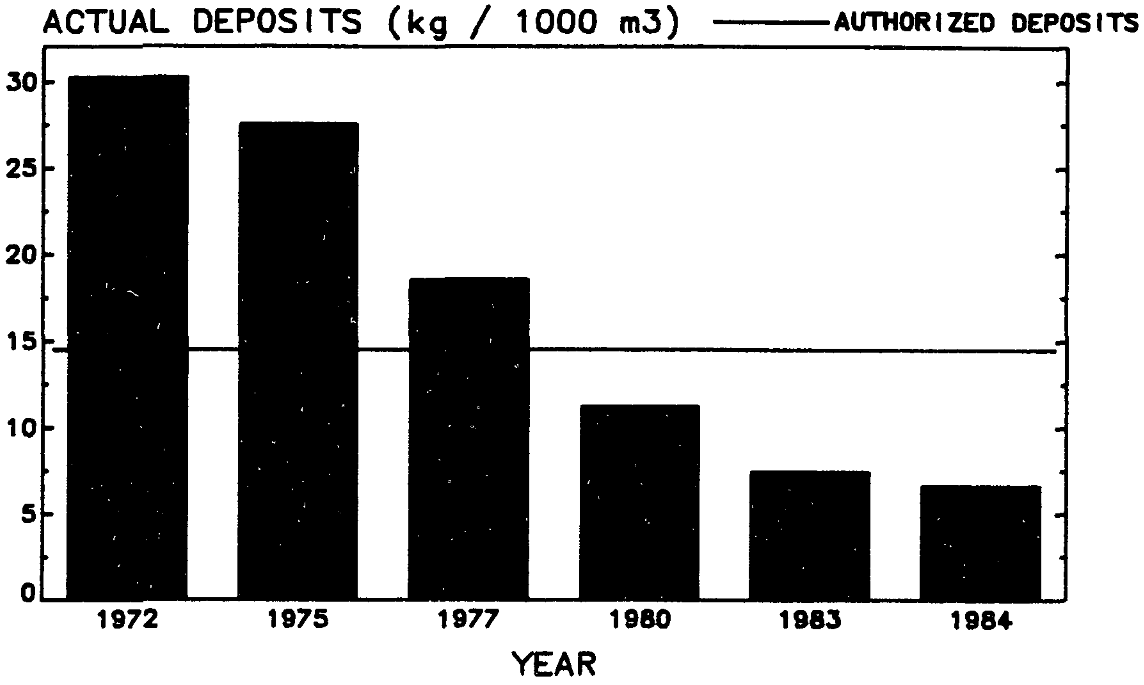


FIGURE 3 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (National - 1972 to 1984)

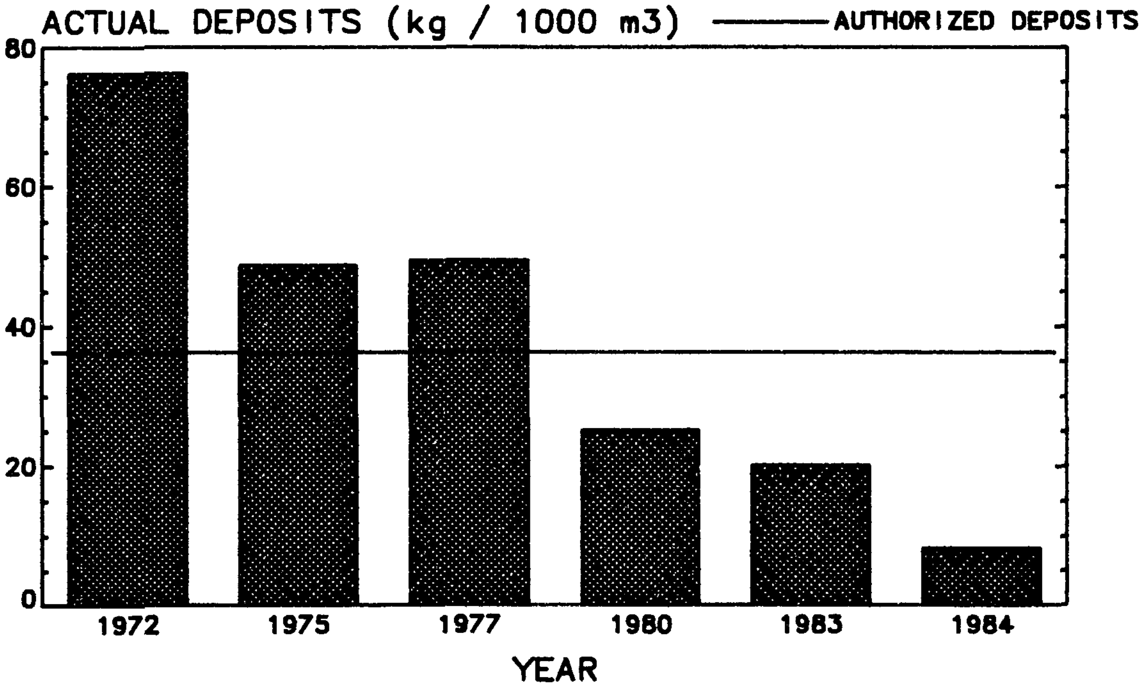


FIGURE 4 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (National - 1972 to 1984)

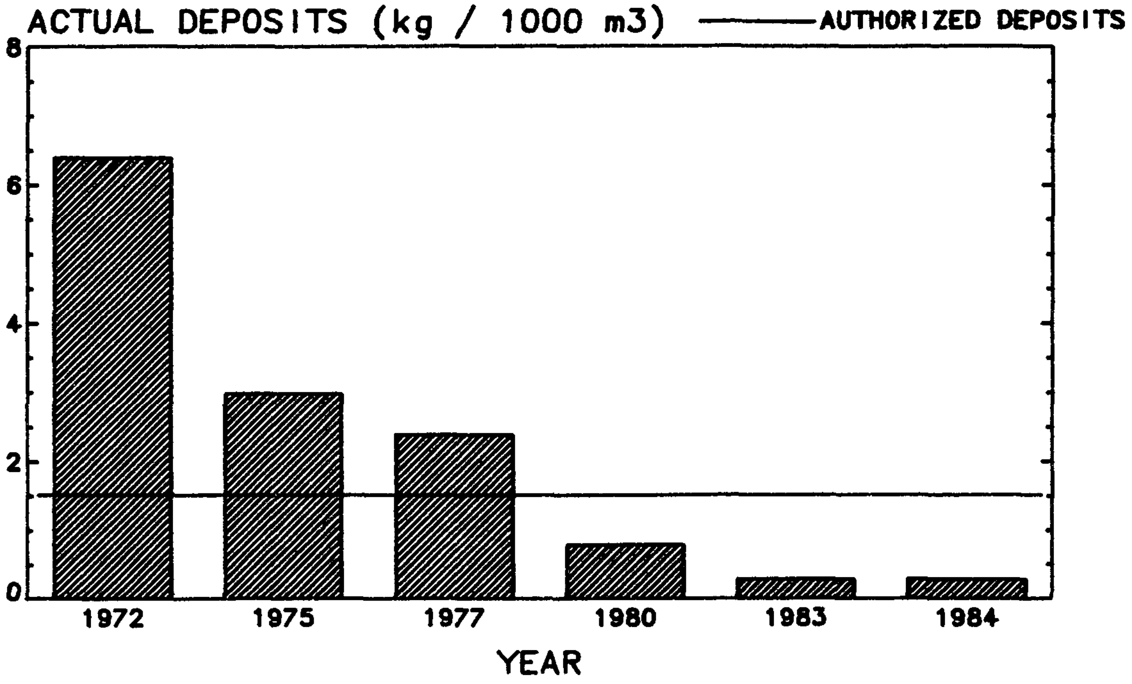


FIGURE 5 AVERAGE ANNUAL DISCHARGES OF PHENOLS (National - 1972 to 1984)

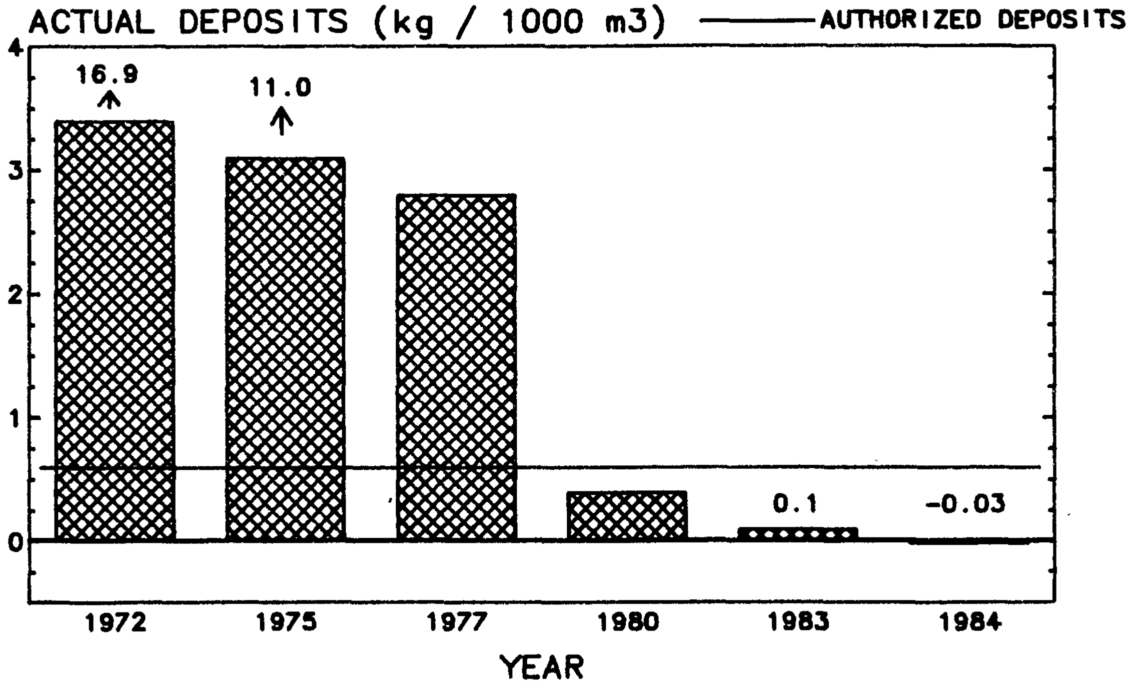


FIGURE 6 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (National - 1972 to 1984)

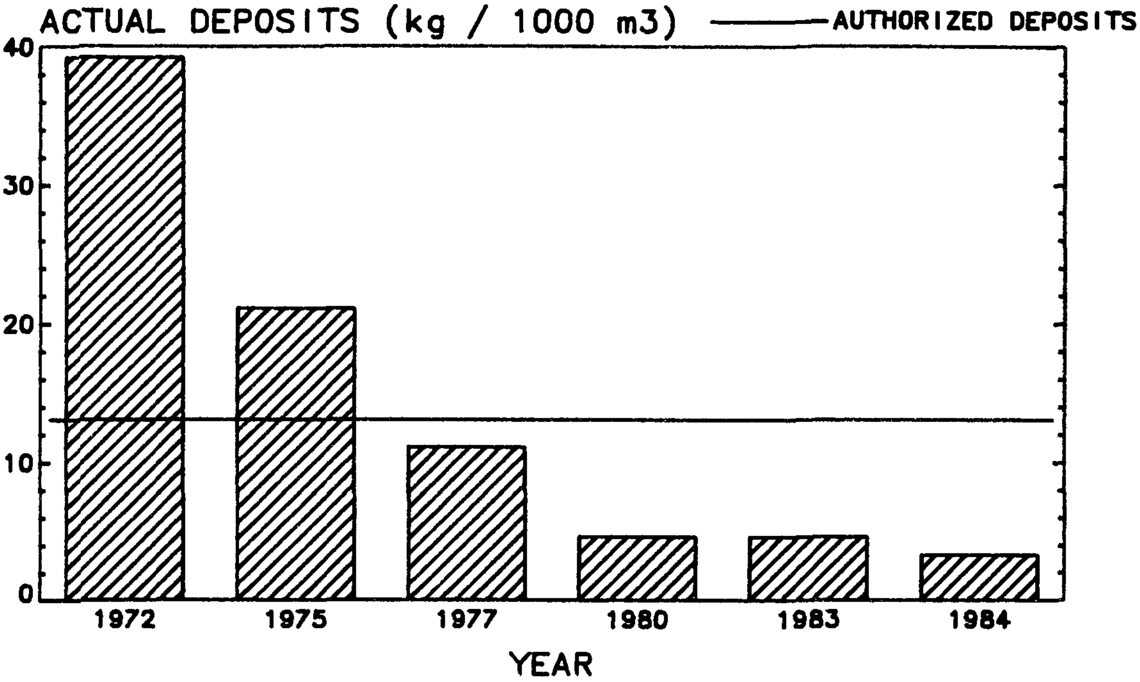


FIGURE 7 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (National - 1972 to 1984)

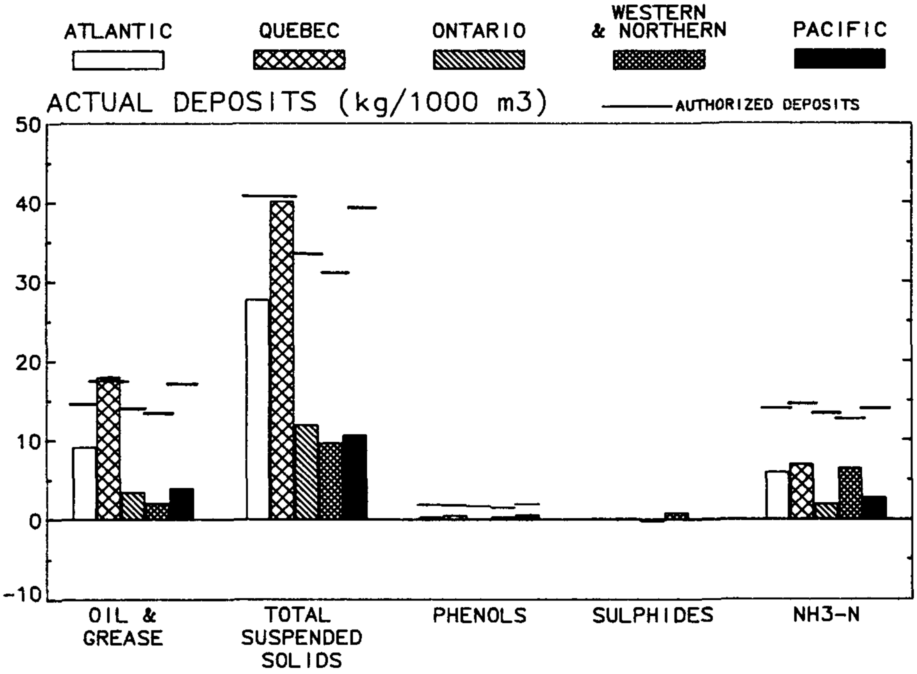


FIGURE 8 COMPARISON OF REGIONAL DEPOSITS OF THE REGULATED PARAMETERS (1983)

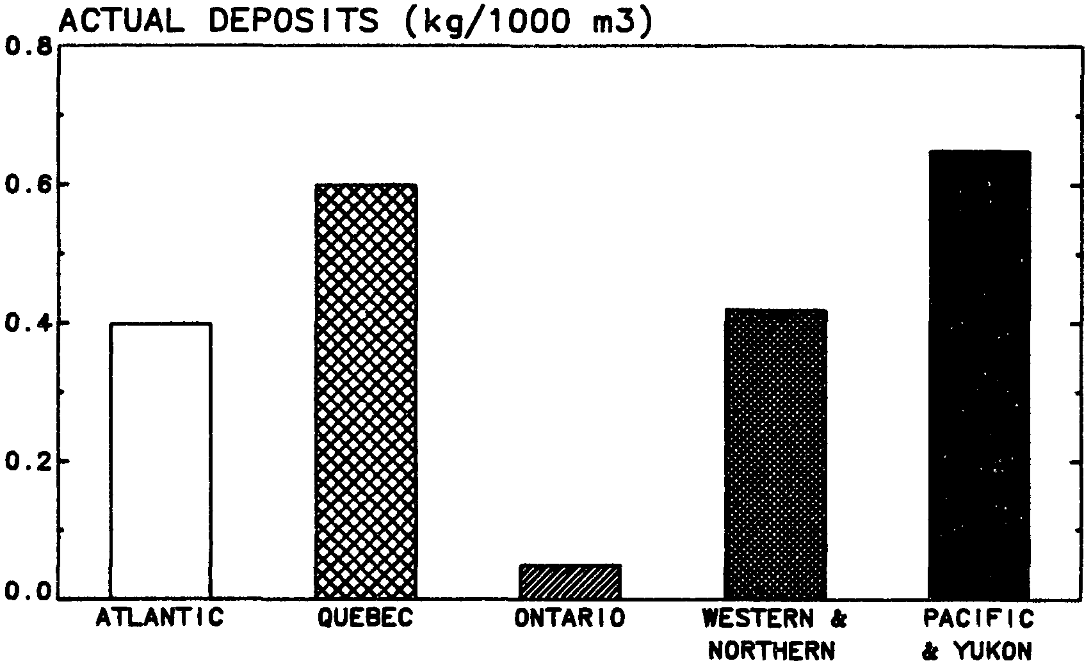


FIGURE 9 COMPARISON OF REGIONAL PHENOLS DISCHARGE LEVELS (1983)

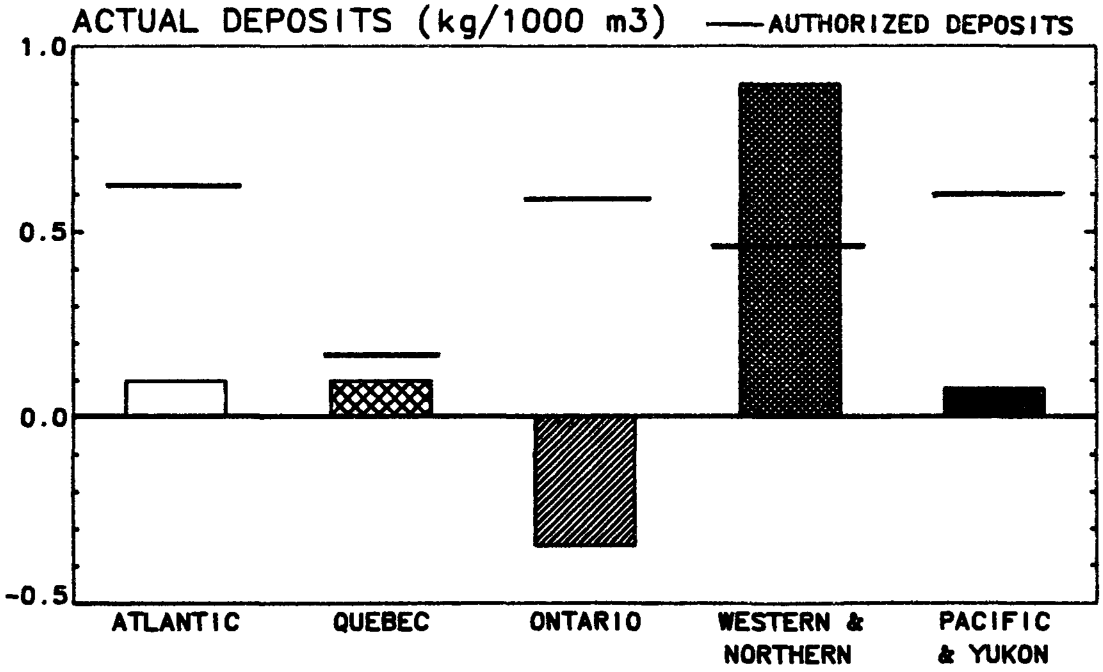


FIGURE 10 COMPARISON OF REGIONAL SULPHIDE DISCHARGE LEVELS (1983)

deposits in other regions were comparable except in Ontario which had a negative value. The Ontario and Pacific regions had the lowest deposits of ammonia nitrogen.

Performance of Refineries Subject to Regulations. In 1983, the four new refineries that were assessed were in compliance with the monthly amounts 97% of the time; with the daily limits more than 99.6% of the time; and with the stormwater limits 100% of the time. A regional breakdown of compliance with the monthly amounts of the regulations by parameter is provided in Table 21. The only low performance was for sulphide in the Western & Northern region with compliance only 75% of the time for the sulphide limits. The refinery responsible for the large deposits of sulphide was Turbo in Balzac which violated the monthly amounts for sulphide 50% of the time. The Turbo refinery started operation late in 1982 and these violations can be attributed to difficulties in bringing the process units on stream. In 1984, the refinery improved its performance, reducing violations of the sulphide monthly amounts to 14% of the time. In 1983, 57% of the violations that exceeded the monthly amounts were less than 24% above the limits, and all of them were less than 50% above the limits.

TABLE 21 PERCENT COMPLIANCE OF REFINERIES IN EACH REGION WITH MONTHLY AVERAGE LIMITS AS SET IN THE <u>REGULATIONS</u> (1983)

	% of Time in Compliance with the Regulations					
Region*	Oil and Grease	Total Suspended Solids	Phenols	Sulphide	Ammonia Nitrogen	Total
Ontario	100	100	100	100	100	100
Western & Northern	96	100	100	75	100	94
Canada	98	100	100	88	100	97

* There are no refineries subject to the regulations in the other regions

Overall performance in 1984 for the new refineries was: 98% of the time in compliance with the monthly amounts; 100% of the time with the one-day amounts and stormwater limits; and 99.9% of the time for the maximum daily amounts.

In 1983, of all the annual deposits from the new refineries, only Turbo's sulphide discharge was above the authorized level. In 1984, all the annual deposits were below the limits. On the average, 84% of the tests that are required by the regulations were reported in 1983. Turbo reported only 60% of the tests required and was responsible for the low national average.

Net Discharges 1983. Although the federal regulations and guidelines limit the deposits of several contaminants on a production basis, it would be useful to evaluate the net deposits (in kg/d) to have a better appreciation of the quantity discharged to the environment by the petroleum refining industry. Table 22 provides the total net loadings discharged in 1983 to the various receiving waters. The St. Lawrence River received the highest net load of contaminants, compared to other receiving waters. This is partly due to the large number of refineries that discharged into it. For the same reason, the St. Clair River receives the second highest level of suspended solids, and oil and grease.

The national net discharges of the regulated parameters from 1972 to 1983 are presented in Table 23. As shown, there has been a general downward trend except for discharges of sulphide which reached an all-time low in 1980, and then increased by 26% in 1983 (still below the authorized limits). Since 1972, the discharge levels of all the parameters have been reduced, ranging from 75% for total suspended solids to 99% for sulphide. If the 1983 levels are compared to the 1980 levels, reductions ranging from 21% for ammonia nitrogen to 53% for phenols are found. If the 20% decrease in production from the 1980 level is considered, it is apparent that the discharge level of sulphide increased markedly, but some improvements have been made for all the other parameters.

Table 24 presents a regional breakdown of the net discharge levels by contaminant and of the production levels for 1983. If the percent contribution to the national loading is compared with the percent contribution to national production, it is found that: the Atlantic region has almost the same loading and production contribution; Quebec has, for most parameters, a higher loading contribution than production; Ontario has, for all the parameters, a lower loading contribution than production; the Western & Northern region has a higher loading contribution for sulphide; and the Pacific region has a generally lower loading contribution except for phenols where the contribution is higher than production. As shown in Table 25, the Quebec, Ontario and Pacific regions have reduced their 1983 net discharges from the 1980 levels. The Atlantic region reported an increase in the net discharges of oil and grease, total suspended solids, and ammonia nitrogen. The Western & Northern region also had an increase in the net deposits of sulphide, ammonia nitrogen and phenols. These increases are not necessarily a reflection of the regional performance but rather a credit to the very low levels that were achieved

TABLE 22 NET LOADINGS TO EACH RECEIVING WATER BODY (1983)

	Net Loadings (kg/d)*				
Receiving Water	Oil and Grease	Total Suspended Solids	Phenols	Sulphide	Ammonia Nitrogen
Halifax Harbour, Dartmouth, N.S.	104	402	9	0.03	41
Little River, St. John, N.B.	133	332	2	0.8	115
Conception Bay, Holyrood, Nfld.	10	9	0.2	0.04	0.1
St. Lawrence River, Montreal, Que.	1080	2150	34	6	442
St. Clair River, Sarnia, Ont.	184	694	2	-28	73
Lake Ontario, Mississauga, Ont.	147	379	2	3	72
Lake Erie, Nanticoke, Ont.	8	12	0.1	0.3	14
North Saskatchewan River, Edmonton, Alta.	45	286	0.9	1	21
MacKenzie River, Norman Wells, NWT	13	105	0.3	0.1	0.7
Red Deer River, Bowden, Alta.**	0	0	0	0	0
Bow River, Calgary, Alta.	9	20	0.1	0.02	0.7
McDonald Lake, Balzac, Alta.	0.6	12	0.1	2	2
Burrard Inlet, Ioco, B.C.	61	237	3	0.0	17
Peace River, Taylor, B.C.	4	6	0.6	0.9	25
Off-site Treatment***	246	739	42	46	383

* Net loadings represent annual average.

** No effluent was discharged in 1983.

*** Off-site Treatment includes: municipal sewers in Montreal, Moose Jaw, Regina, Winnipeg North End, Greater Vancouver Regional District, Kamloops, and the Prince George Pulp and Paper Company.

The off-site values for phenols, sulphide and to a lesser degree for ammonia nitrogen may be over estimated since they include stormwater deposits discharged to the Wascana Creek in Saskatchewan. The Co-op refinery, which sends its process water to the Regina sewer and its stormwater to the Wascana Creek, did not provide a breakdown of the two. The same situation applies for the Moose Jaw River in Saskatchewan; however, the quantity discharged by the refinery as a total is very small and would not affect the off-site values.

TABLE 23 SUMMARY OF TOTAL NATIONAL NET DISCHARGES - REGULATED PARAMETERS

	Discharges (kg/d)					% Reduction since*	
Parameter	1972	1975	1977	1980	1983	1972	1980
Oil and Grease	8 300	9 000	6 000	2 980	1 923	77	35
Total Suspended Solids	20 900	15 900	15 900	7 175	5 154	75	29
Phenols	1 800	900	900	200	97	95	53
Sulphide	4 600	3 400	900	50	63**	99	-26
Ammonia Nitrogen	10 900	6 700	3 500	1 533	1 205	89	21
Reference Crude Rate (10^3 m^3/d)	270	320	320	320	256	5	20

* compared to 1983 data

** Ontario's negative value is not included.

TABLE 24 NATIONAL PERCENT PRODUCTION AND DEPOSITS (1983)

	Percent of National				
	Atlantic Region	Quebec Region	Ontario Region	Western & Northern Region	Pacific & Yukon Region
Production (%)	10.4	26.0	32.2	21.7	9.7
Deposits (%)					
Oil and Grease	12.7	61.2	15.3	5.6	5.2
Suspended Solids	14.6	51.5	19.8	9.1	5.0
Phenols	11.4	42.3	4.0	24.2	18.1
Sulphide	1.5	12.6	0	82.6	3.3
Ammonia Nitrogen	12.6	37.6	12.9	30.9	6.0

TABLE 25 PERCENT REDUCTION OF NET DEPOSITS AND OF PRODUCTION BETWEEN 1980 AND 1983

	% Reduction by Region					
	Atlantic	Quebec	Ontario	Western & Northern	Pacific & Yukon	Canada
Reference Crude Rate	40	22	18	11	8	21
Oil and Grease	-27	32	48	34	62	35
Total Suspended Solids	-3	34	36	7	29	29
Phenols	9	65	74	-19	56	53
Sulphide	61	78	570	-7776*	83	-26
Ammonia Nitrogen	-5	41	61	-364	44	21

* mostly Co-op

in 1980. Despite these increases, all the 1983 net deposits in each region remained below the authorized levels except for the sulphide deposits in the Western & Northern region.

4.4.2 **Atlantic Region Assessment.** The four operating refineries in the Atlantic region all have an "existing" status and are subject to the guidelines. The individual performances of the refineries in this region for 1983 are presented in Appendix B.

In 1983, the region was in compliance with the monthly amounts 96% of the time. Texaco was in full compliance with all the limits; Irving and Ultramar were in compliance with the monthly amounts more than 95% of the time. The overall performance of each refinery is provided in Table 20. As shown in Figure 2, half of the deposits that exceeded the monthly amounts were less than 24% above the limits, and all of them were less than 99% above the limits. The one-day amounts and the maximum daily amounts were exceeded very few times (in compliance more than 99% of the time). All the limits for sulphide and pH were always met; toxicity was within the limit 92% of the time; and the other four parameters were in compliance with the monthly amounts at least 95% of the time.

The percentage of time the region was in compliance with the monthly amounts went from 98% in 1980 to 96% in 1983 and to 94% in 1984. The situation improved greatly in 1985, however, when the percentage increased to 97.

The annual regional deposits between 1972 and 1984 are presented for each parameter in Figures 11 to 15. The performance in 1983 declined from that of 1980. Only sulphide deposits were reduced by 40% in 1983; all the other parameters experienced increases of 50 up to 114%. The deposits of 1984 appear to be somewhat unchanged compared to 1983. It is important to stress, however, that all the actual deposits during 1980, 1983 and 1984 were far below the authorized levels so perhaps these statistics are more a credit to the region's achievement during 1980 than a criticism of its 1983 and 1984 performance.

A comparison of the annual deposits from each refinery in 1983 is provided for all the parameters in Figures 16, 17 and 18. The discharges of all refineries were below the authorized deposits. Esso--Dartmouth had the highest discharge of total suspended solids and phenols and the lowest sulphide discharge; Irving--St. John had the highest ammonia and the second lowest phenols discharge; Texaco--Dartmouth had the best performance overall; and Ultramar--Holyrood had the highest oil and grease discharges (very close to the discharge limits).

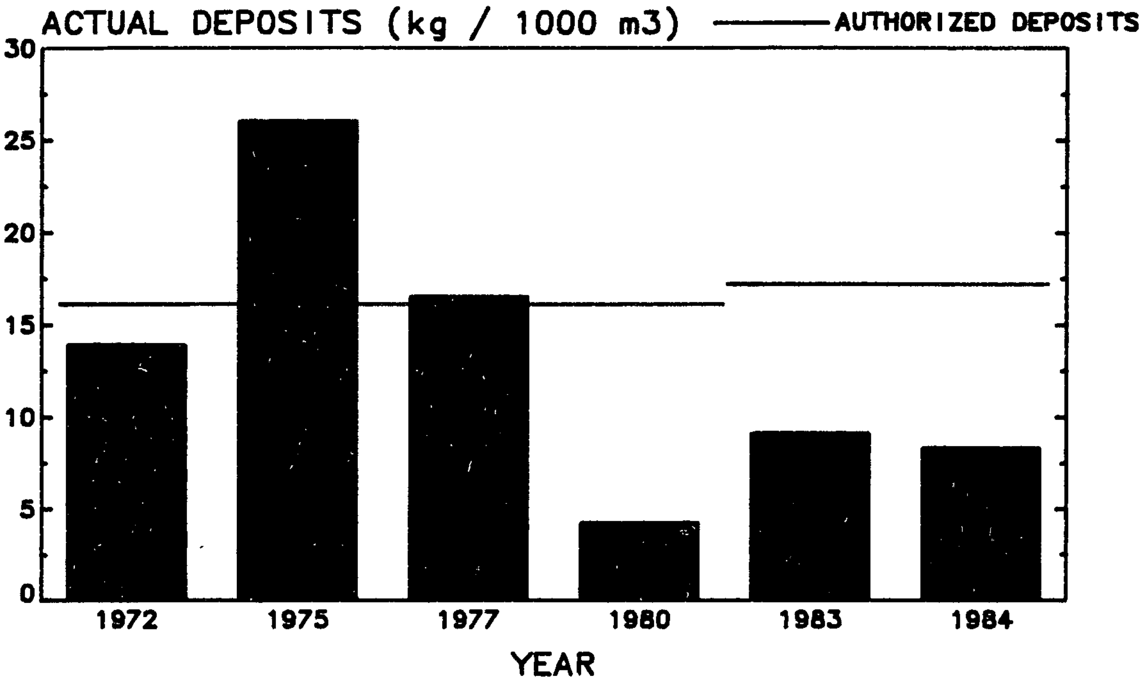


FIGURE 11 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Atlantic Region - 1972 to 1984)

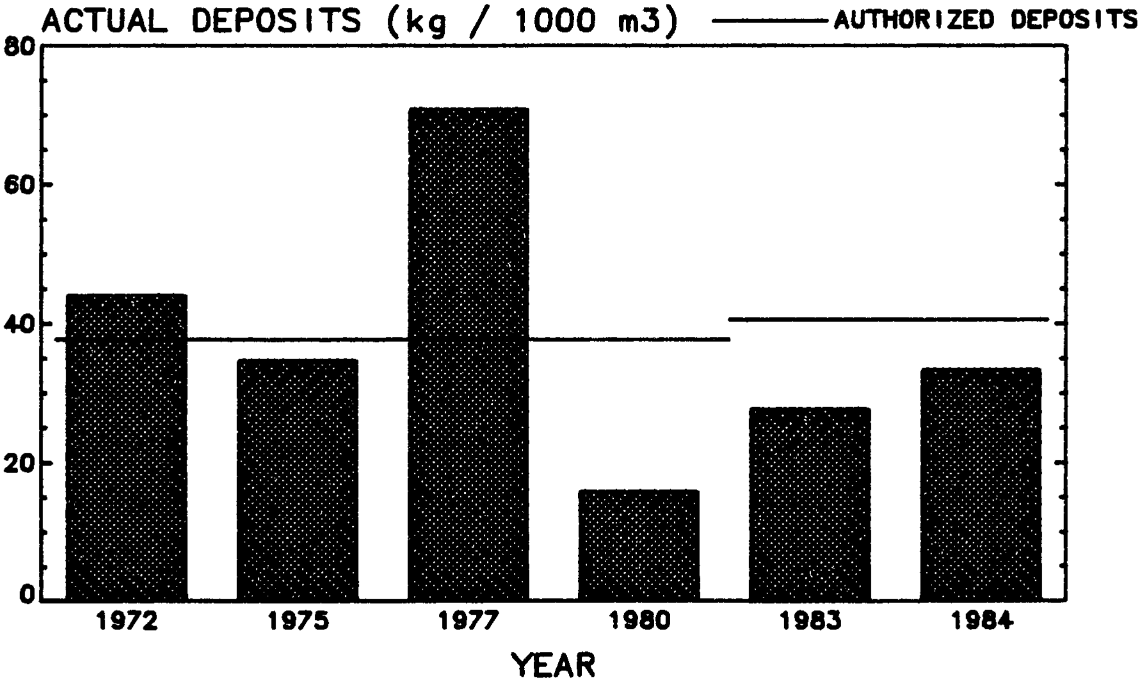


FIGURE 12 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Atlantic Region - 1972 to 1984)

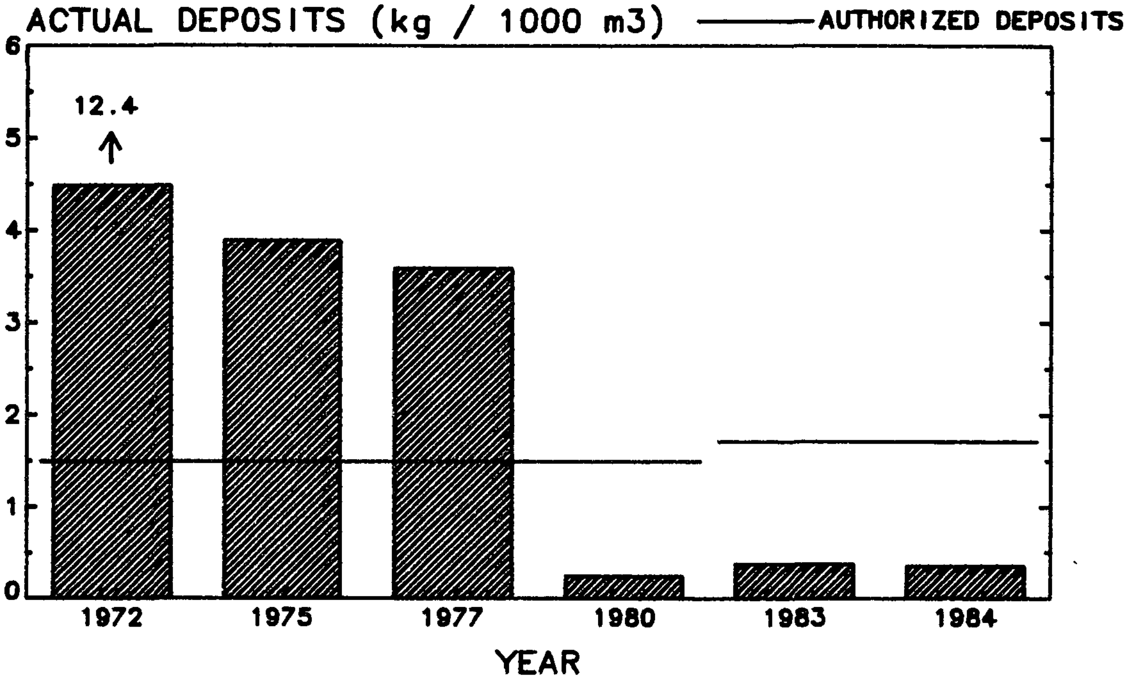


FIGURE 13 AVERAGE ANNUAL DISCHARGES OF PHENOLS
(Atlantic Region - 1972 to 1984)

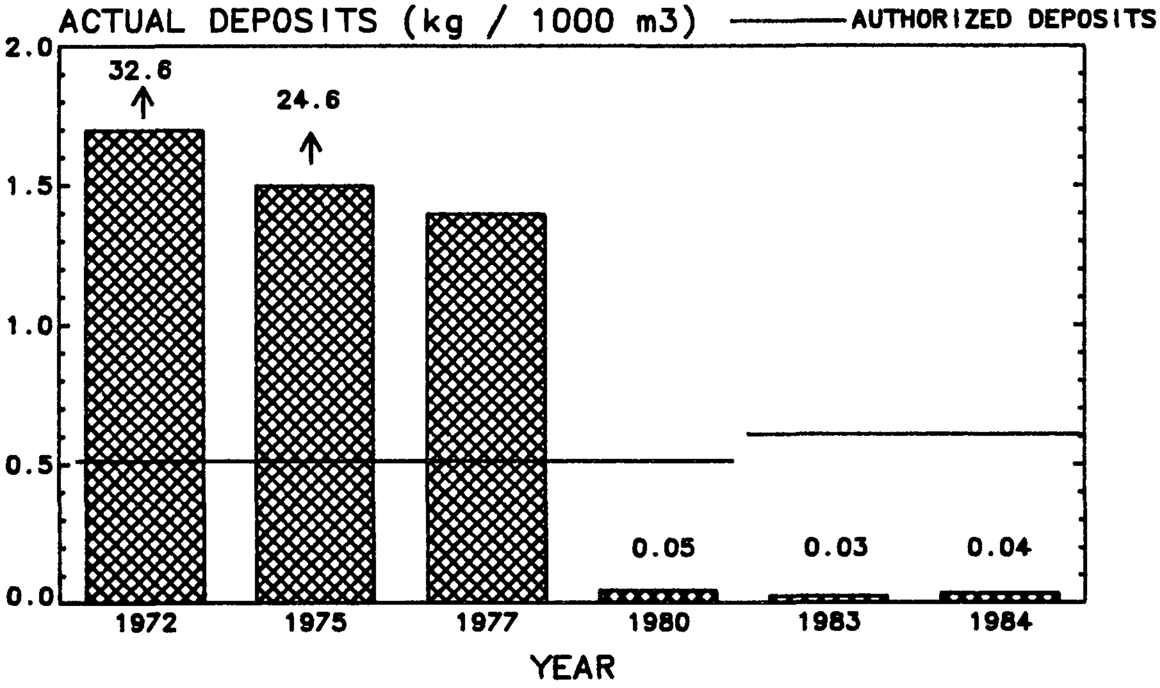


FIGURE 14 AVERAGE ANNUAL DISCHARGES OF SULPHIDE
(Atlantic Region - 1972 to 1984)

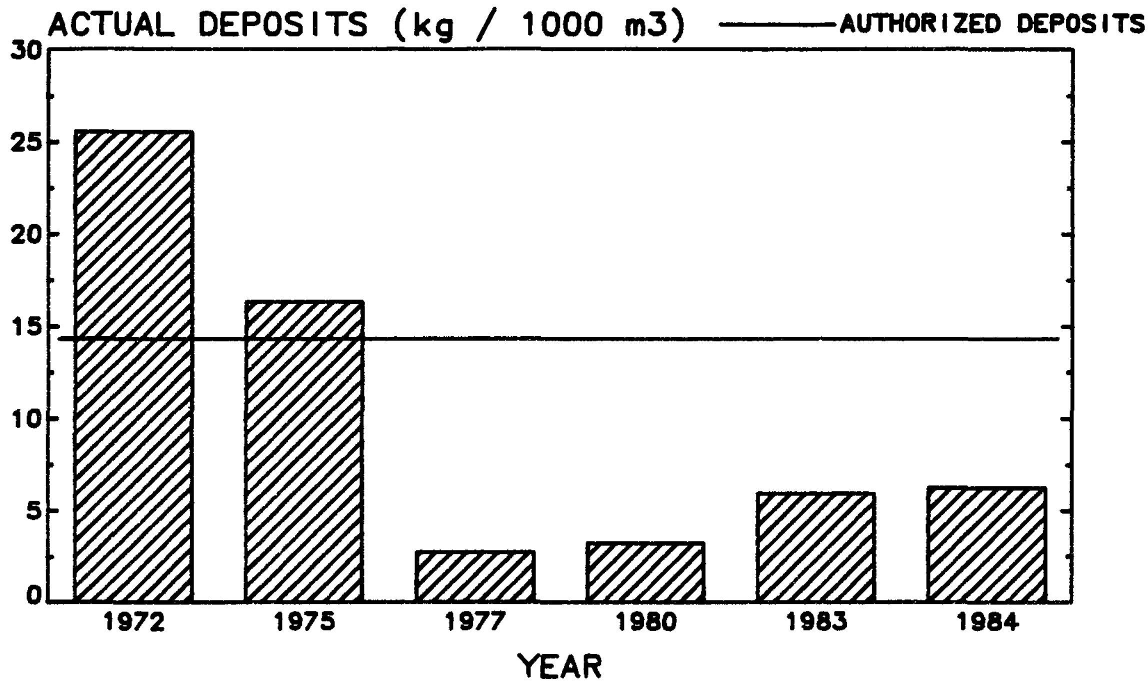


FIGURE 15 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Atlantic Region - 1972 to 1984)

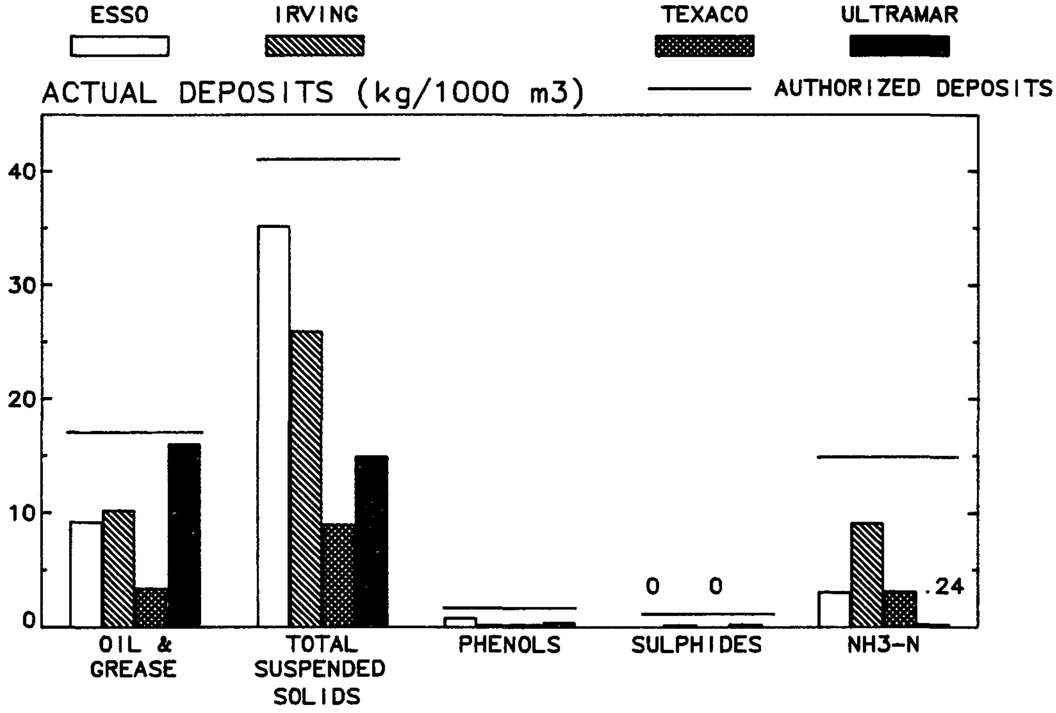


FIGURE 16 REFINERY DISCHARGE LEVELS BY PARAMETER (Atlantic Region - 1983)

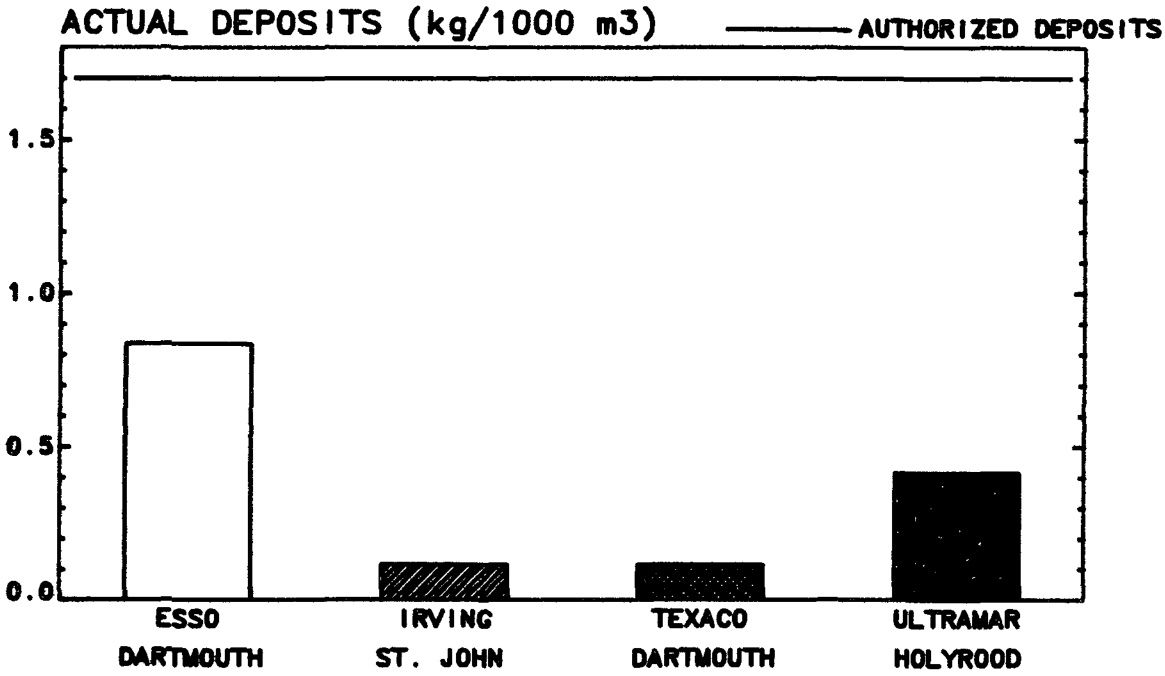


FIGURE 17 PHENOLS DISCHARGE LEVELS BY REFINERY
(Atlantic Region - 1983)

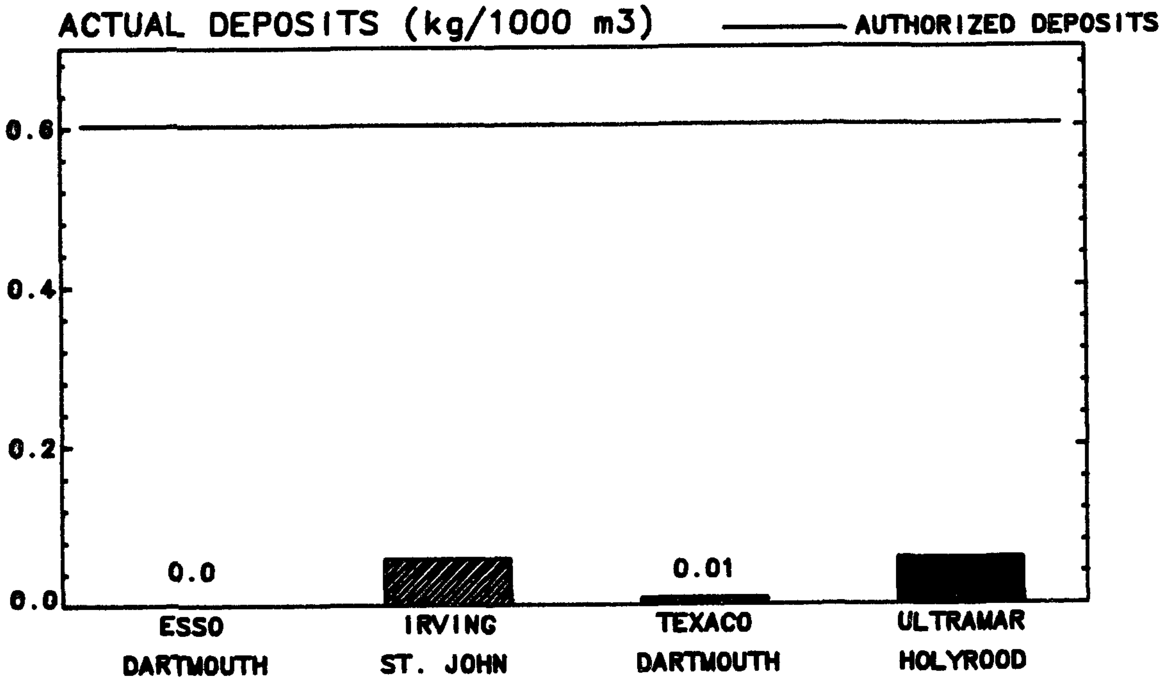


FIGURE 18 SULPHIDE DISCHARGE LEVELS BY REFINERY
(Atlantic Region - 1983)

Of all the requested tests in the region, 10% were not reported in 1983 and 7% were not reported in 1984. The 1983 production was reduced by 40% compared to 1980 level, and remained fairly steady in 1984. This reduction was not caused by the permanent shut down of Ultramar--Holyrood in June 1983, but rather by Irving's decrease in production. The performance of each refinery in this region is presented in Table 26 giving 1983 and 1984 values for each parameter.

TABLE 26 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Atlantic Region - 1983, 1984)

		% of time not in compliance																
		Oil and Grease			Total Suspended Solids			Phenols			Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery		M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	N	N
Esso Petroleum (Dartmouth)	1983	0	0	0.9	17	2	3	17	0	3	0	0	0	0	0	0	0	0
	1984	8	2	0.6	42	5	5	8	0	0.7	0	0	0	0	0	0	0	8
Irving (St. John)	1983	0	0	0	0	0	0	0	0	0	0	0	0	17	0.6	0	0	25
	1984	0	0	0.6	17	2	0	0	0	0	0	0	0	17	2	6	0	17
Texaco (Dartmouth)	1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ultramar (Holyrood)	1983	33	6	3	0	0	0	0	0	0	0	0	0	0	0	0	-	-

M : monthly amount; O : one-day amount; N : maximum daily amount

Esso Petroleum--Dartmouth, N.S. Esso has a secondary treatment system (activated sludge) and discharges its treated effluent into Halifax harbour.

In 1983, Esso was in compliance with the federal guidelines for sulphide, ammonia nitrogen, pH, and toxicity. For oil and grease, only the maximum daily amount was exceeded (less than 1% of the time). However, numerous deposits of total suspended solids and phenols exceeded the authorized level. The company experienced operational problems which shocked the biological system and contributed to some of the high deposits, particularly total suspended solids. For phenols, the first discharge exceeding the monthly amount was due to a temporary leak of caustic soda into the system. The second excessive deposit originated from the API tankfarm runoff. In May 1984, Esso upgraded its API separator system with a new ballast water holding tank intended to prevent hydraulic overloading of the separators.

An Environment Canada survey was conducted in September, 1983. The oil and grease discharge was found to exceed the limit; all other parameters were below the limits.

Esso was in compliance with the monthly amounts 93% of the time and more than 99% of the time for the daily limits. Half of the deposits that exceeded the monthly amounts was less than 50% above the limit and the other half was between 50 and 100% above the limit. The annual deposits for 1983 were all below the authorized limits. Of the total number of tests requested, 4% were not reported.

Esso's performance deteriorated in 1984; monthly amounts were exceeded for total suspended solids, oil and grease, and phenols. One monthly amount exceeded the limit by more than 150%, the others by less than 100%. The one-day amount and the maximum daily amount were also exceeded (mainly for total suspended solids). The annual deposits for 1984 remained unchanged from 1983 and were therefore below the authorized limits.

Irving—St. John, N.B. Irving, the largest refinery in the Atlantic region, has a secondary treatment system consisting of an activated sludge process. The treated effluent is discharged into the Little River (which flows into St. John harbour).

Irving was within the allowable limits of the guidelines in 1983 for oil and grease, total suspended solids, sulphide and pH. The monthly amounts for ammonia nitrogen was exceeded twice (less than 24% above the limit) because of problems with the overhead condenser in the atmospheric tower. After the problems were corrected, they remained below the allowances. The one-day amount limit was exceeded once, again for ammonia nitrogen and there were three toxicity failures.

The Environment Canada survey in August 1983, indicated that Irving was above the limits for total suspended solids and recorded a 100% fish mortality with the 96-h flow-through bioassay.

In general, Irving performed well during 1983 with more than 95% of the time in compliance with all the limits. The annual deposits were all below the limits. Twenty percent of the tests were not reported, mainly for the pH values (only 43% were reported).

In 1984, the company had problems with total suspended solids, ammonia nitrogen and toxicity. There were two deposits in excess of the monthly amount for total suspended solids and the same number for ammonia nitrogen. Half of these monthly amounts were above the limit by between 50 and 100% and the other half exceeded the limit by less than 50%. A number of deposits in excess of the daily limits for ammonia nitrogen and total suspended solids occurred. The 1984 average deposits were slightly higher than in 1983 but were still below the authorized amounts.

Texaco—Dartmouth, Nova Scotia. Texaco treats its effluent with an activated sludge biological system and then discharges it into Halifax harbour (Eastern Passage).

The company operates under the guidelines, and had an excellent performance in both 1983 and 1984 with a 100% compliance for all the parameters. In addition, Texaco reported 100% of the requested tests for the same period.

An Environment Canada survey performed in January 1983, however, registered a deposit exceeding the limit for total suspended solids, and the fish mortality was 100% for the 96-h flow-through bioassay. This is in sharp contrast to the 0% fish mortality reported by Texaco for all the twelve 24-h static bioassays done in 1983. In the 1984 Environment Canada survey, the deposits were all below the authorized levels and the effluent was not toxic to fish.

Ultramar—Holyrood, Nfld. Ultramar ceased production after June 1983; therefore, the following assessment is only for the period the refinery was in operation during that year. The refinery had a primary treatment system and sent the treated effluent into Conception Bay.

Ultramar was in compliance with the guideline limits for all the parameters except oil and grease. Two deposits were in excess of the monthly amount, and few above the daily limits; all were due to operating problems with the API separator. One of these monthly amounts exceeded the limit between 50 and 100%, the other was less than 24% above the limit. The company did not report any toxicity tests and the overall percentage of tests not reported was 30%.

4.4.3 **Quebec Region Assessment.** In 1983, six refineries were operating in Quebec, two of which were closed and decommissioned in 1983 (Esso in November and B.P. in July). All the refineries have an "existing" status and are subject to the guidelines. Gulf, Shell, and Petro-Canada treated a combined effluent generated by the refinery and by an adjacent petrochemical plant. The 1983 individual refinery performance is shown in Appendix B.

In some cases, excessive allowable deposits were given to refineries. This occurred when the refineries did not declare a revised reference crude rate when their average stream day crude rate (sustained for two consecutive months) was less than 85% of the last declared RCR. The refineries should, in the future, declare a revised RCR when appropriate. Also, the refineries in Quebec did not analyze their intake water and, therefore, their actual deposits were overestimated because they were not based on net loadings (as specified in the regulations and guidelines) but rather on total deposits.

The 1983 performance was 79% of the time in compliance with the monthly amounts. The refineries that contributed to this low average were Shell (with 69% of the time in compliance), Petro-Canada (73%), Esso and Ultramar (78% each). As illustrated in Figure 2, almost 60% of the deposits that exceeded the monthly amounts were less than 50% above the limit and almost all of them were less than 200% above the limit. The one-day amount and the maximum daily amount were each in compliance 96% of the time. Parameters that were exceeded most often were oil and grease (exceeded 48% of the time for the monthly amounts), total suspended solids (34% of the time) and, to a lesser degree, ammonia nitrogen and fish toxicity.

The overall regional performance has improved since 1980. The percentage of time the region was in compliance with the monthly amounts increased from 73% in 1980 to 79% in 1983 and to 84% in 1984.

A trend analysis of the annual regional deposits between 1972 and 1984 is illustrated in Figures 19 to 23. Although the region's performance improved in 1983 over the 1980 level, with decreases in deposits of all five parameters, some deposits were still high. Oil and grease deposits, for example, were above the limit and total suspended solid deposits were just below the limit. Nevertheless, the deposits continued to improve and in 1984, the deposits of all the parameters were noticeably below the limits.

The 1983 discharge levels for each refinery in the region are presented in Figures 24 to 28. The discharges from all the refineries were below the limits for phenols, sulphide and ammonia nitrogen. The highest discharge of phenols was from Petro-Canada and the lowest was from B.P.; for sulphide, Esso had the highest discharge and Shell had the lowest; and for ammonia nitrogen, B.P. had the highest and Gulf the lowest. The authorized deposits for the other two parameters were each exceeded by two refineries: Petro-Canada and Ultramar for oil and grease; Shell and Gulf (Gulf was slightly above the limit) for total suspended solids.

More than 90% of all requested tests in the region were reported. The production in 1983 was 22% lower than the 1980 level and a further decrease of 12% was registered between 1983 and 1984. These reductions were mainly caused by refinery closures. The performance of each refinery in this region is presented in Table 27 giving 1983 and 1984 values for each parameter.

Gulf—Montreal. The Gulf refinery also has petrochemical processes which do not fall under the federal regulations and guidelines. The refinery and the chemical plant wastewater are treated in the same system; therefore, the combined treated effluent is considered in the compliance assessment. Gulf has an activated sludge treatment system and sends its treated effluent via the Montreal municipal sewer to the St. Lawrence River.

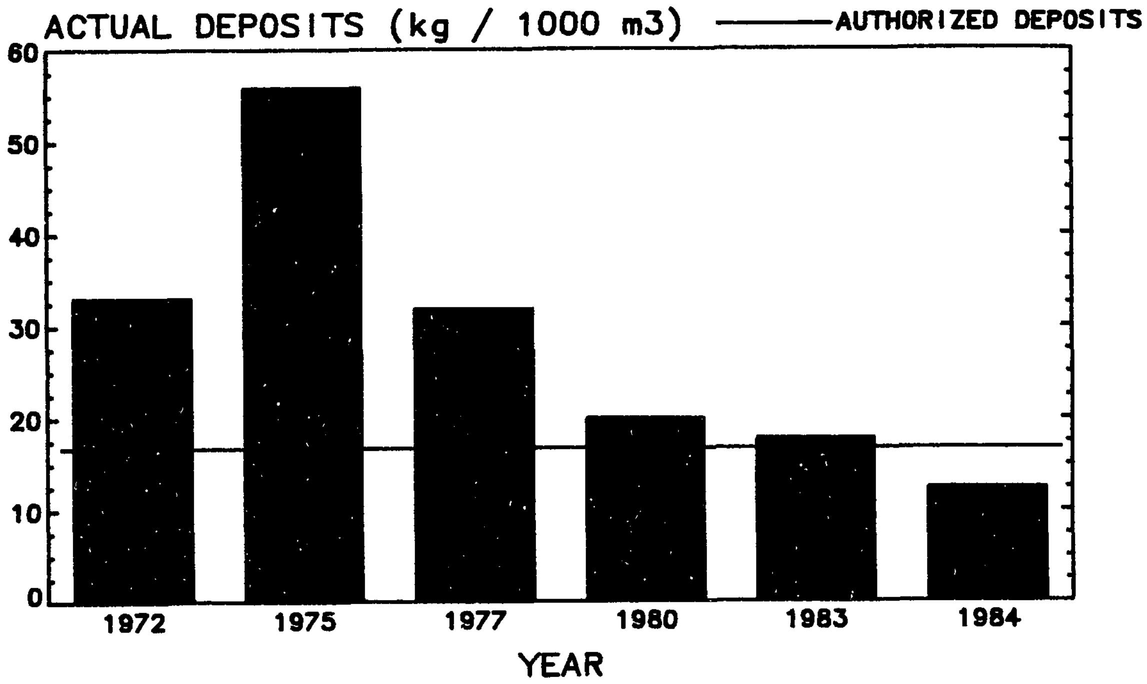


FIGURE 19 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Quebec Region - 1972 to 1984)

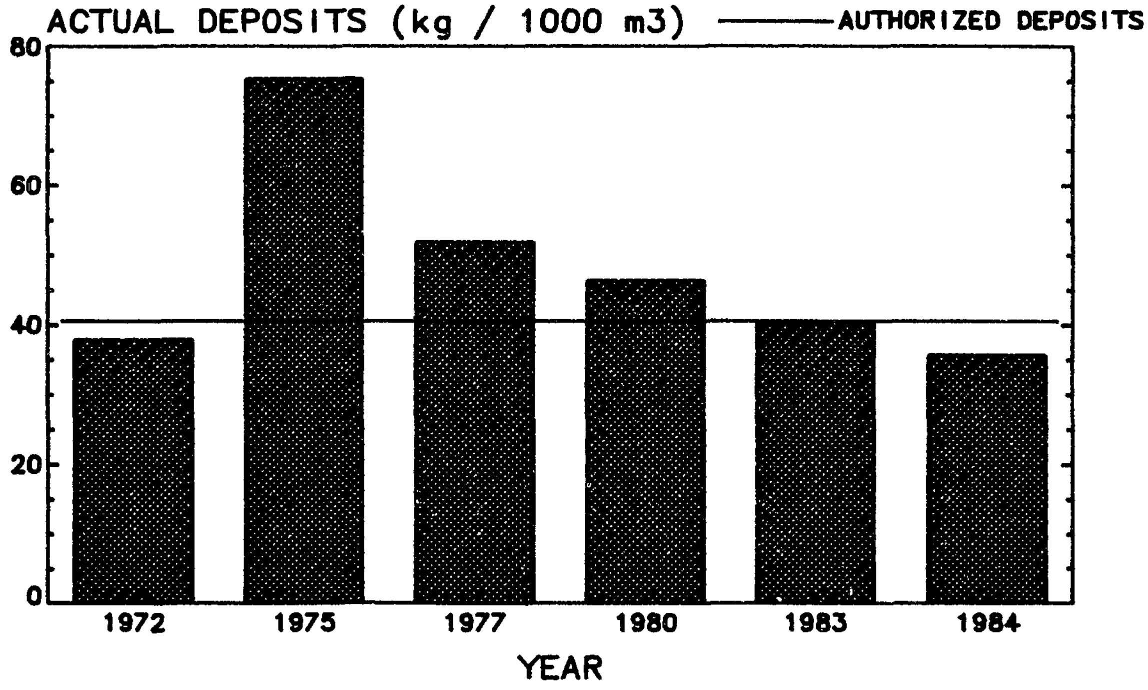


FIGURE 20 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Quebec Region - 1972 to 1984)

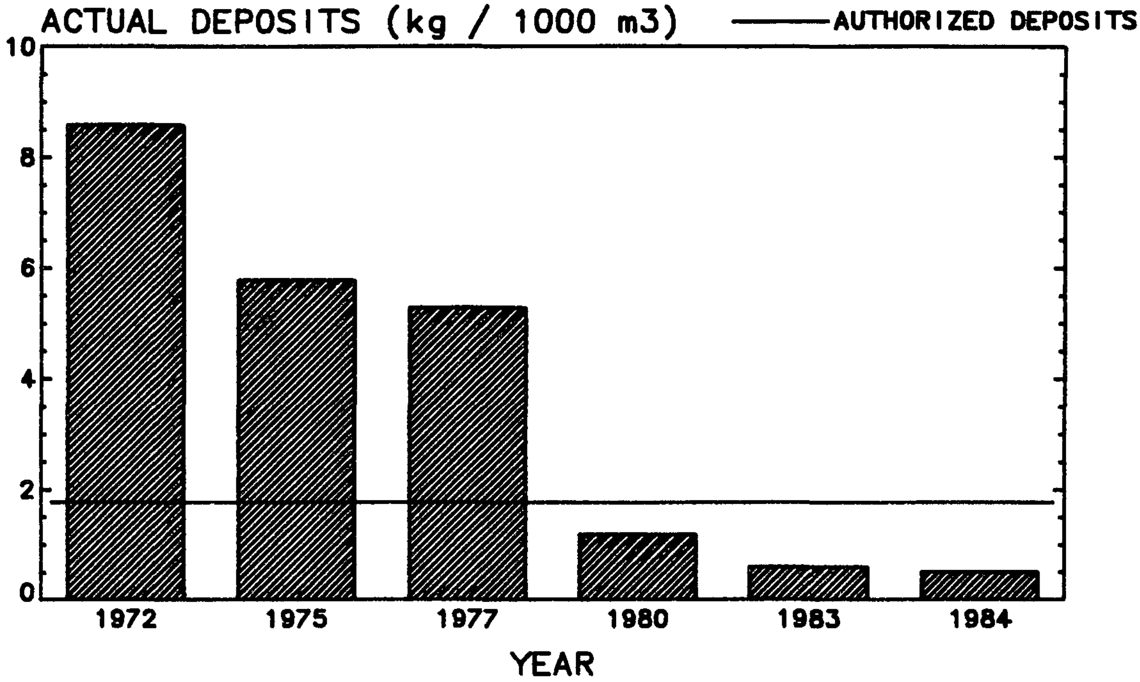


FIGURE 21 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Quebec Region - 1972 to 1984)

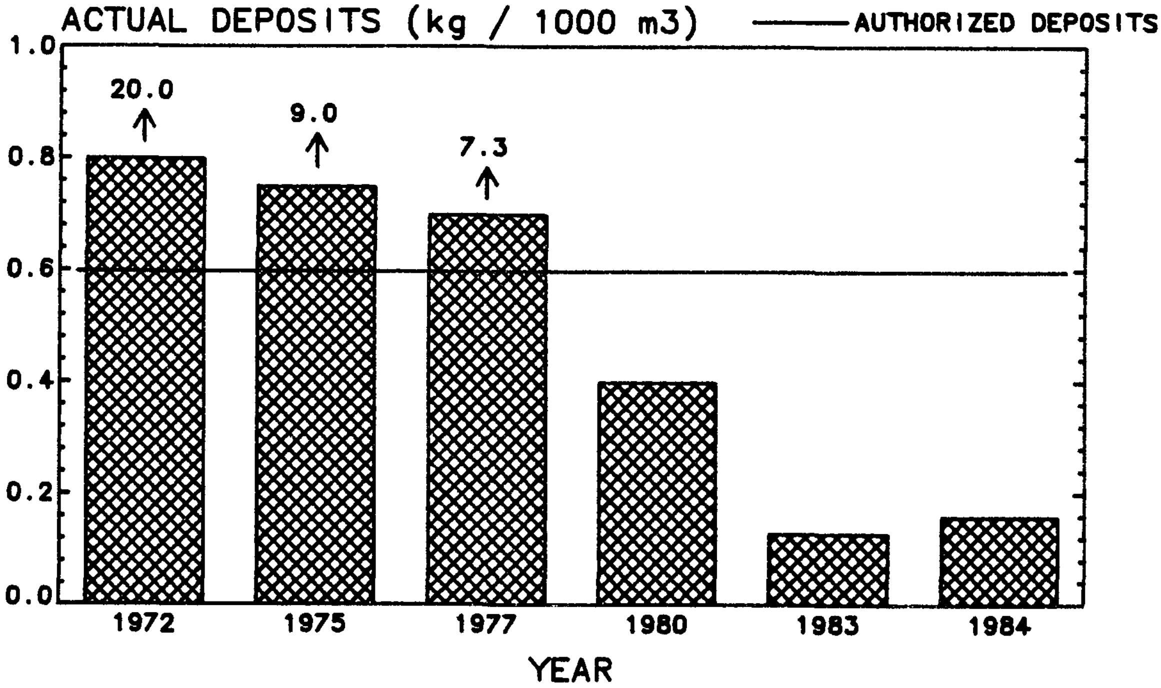


FIGURE 22 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Quebec Region -1972 to 1984)

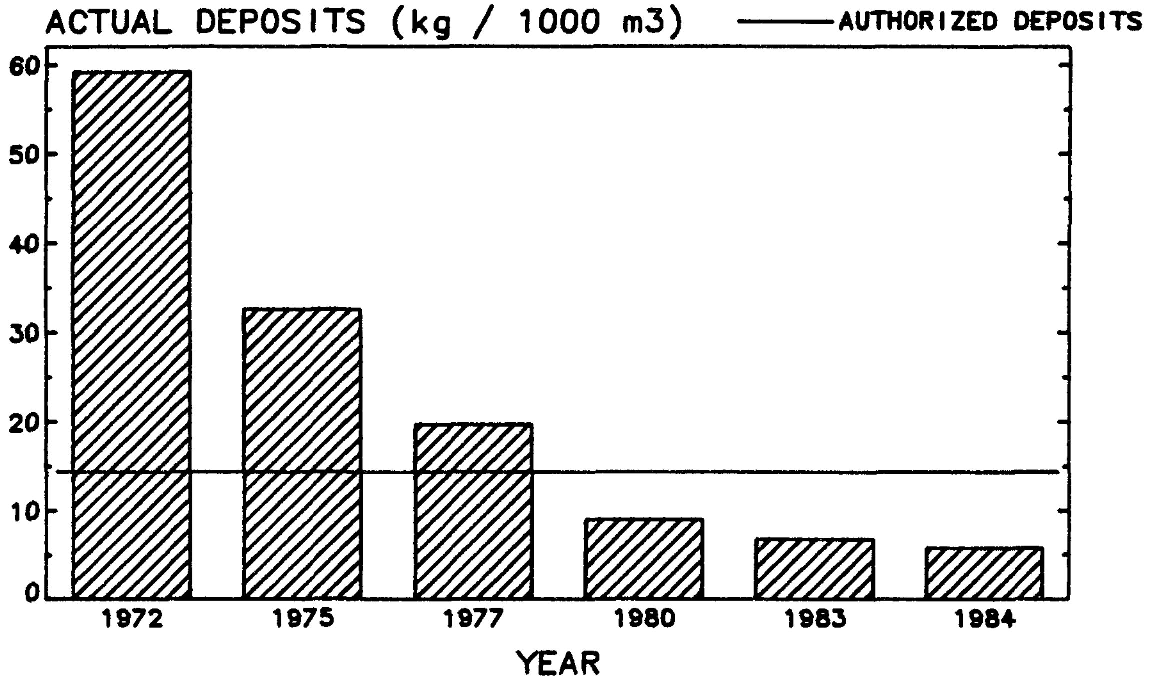


FIGURE 23 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Quebec Region - 1972 to 1984)

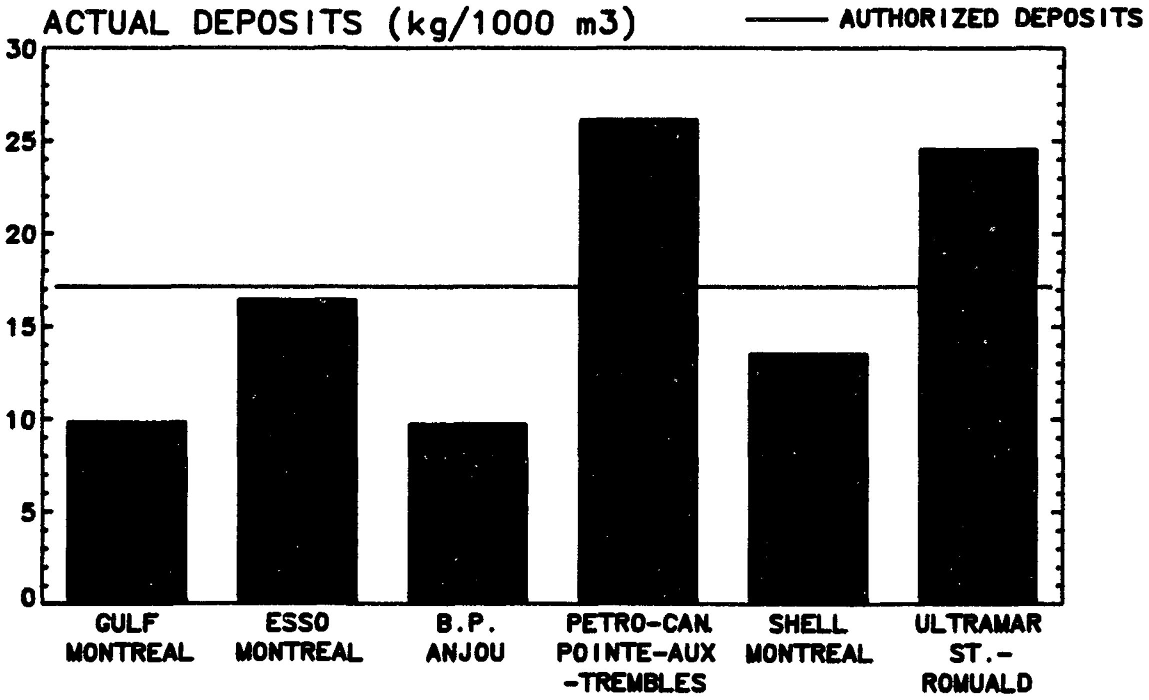


FIGURE 24 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Quebec Region - 1983)

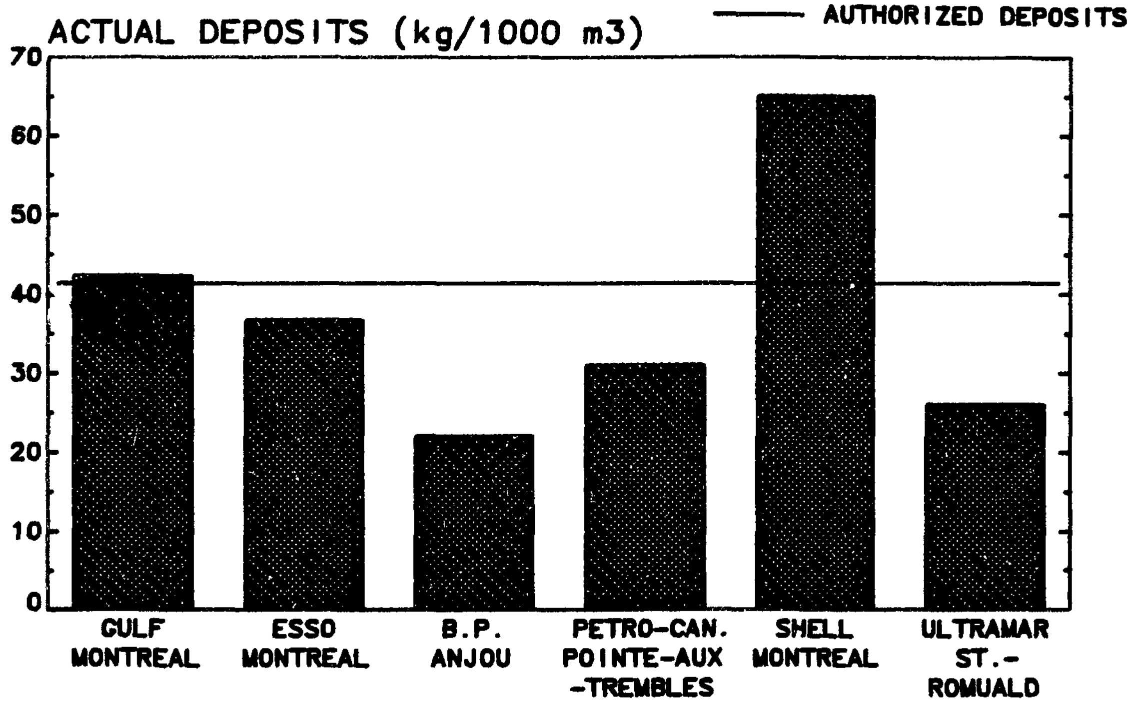


FIGURE 25 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Quebec Region - 1983)

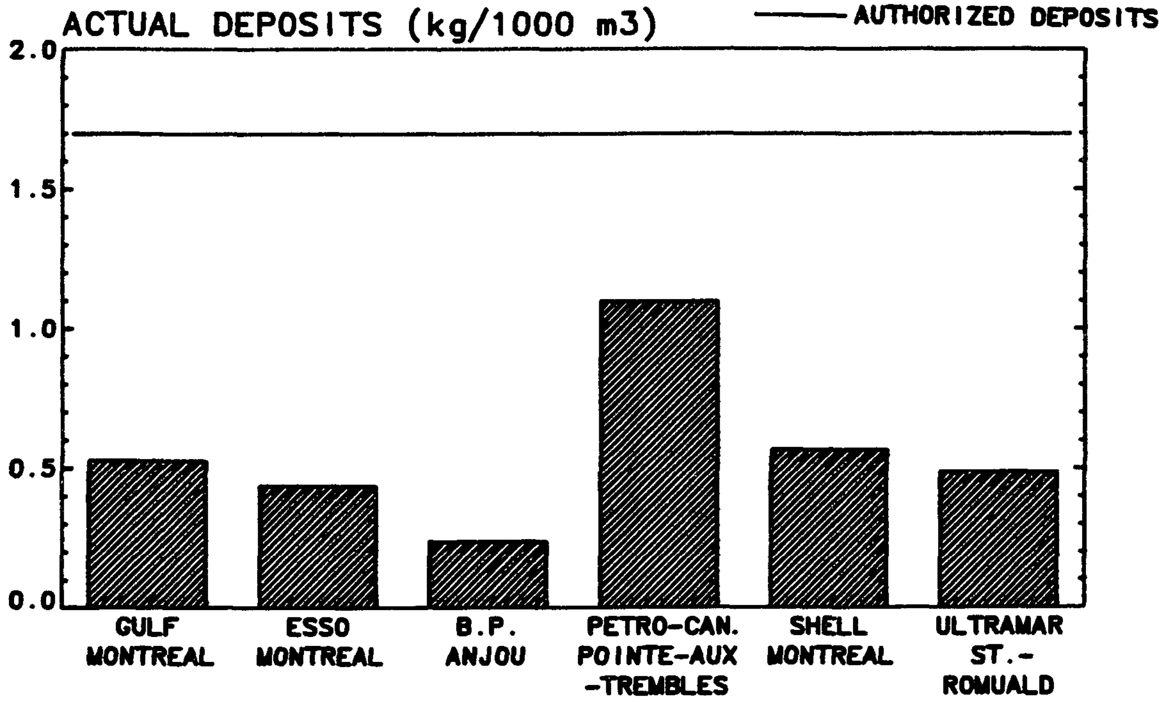


FIGURE 26 PHENOLS DISCHARGE LEVELS BY REFINERY (Quebec Region - 1983)

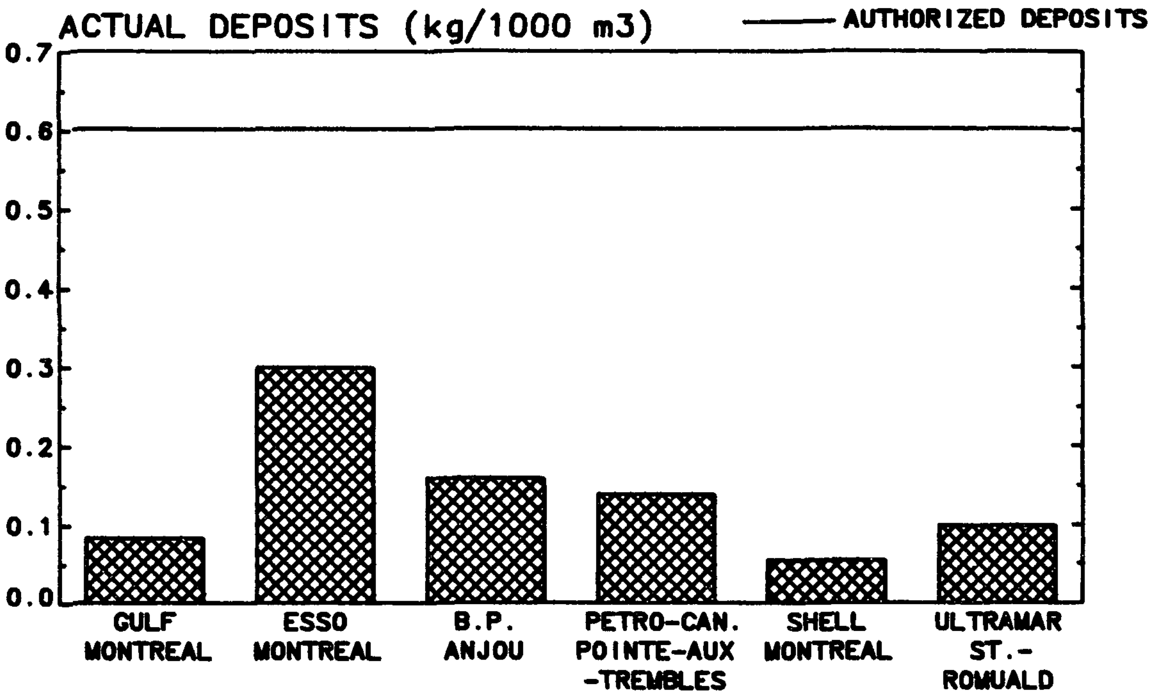


FIGURE 27 SULPHIDE DISCHARGE LEVELS BY REFINERY
(Quebec Region - 1983)

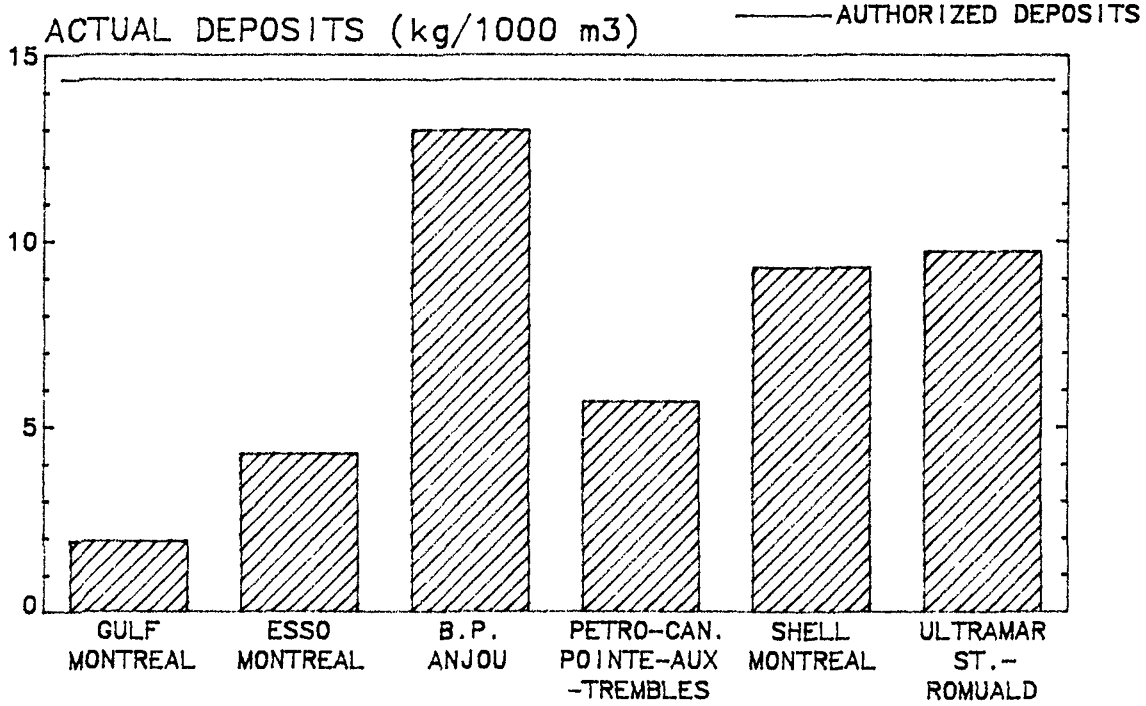


FIGURE 28 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY
(Quebec Region - 1983)

TABLE 27 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Quebec Region - 1983, 1984)

		% of the time not in compliance																
		Oil and Grease			Total Suspended Solids			Phenols			Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery		M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	N	N
Gulf (Montreal)	1983	17	3	2	42	11	12	0	2	3	0	0	0	0	0	0	0.6	0
	1984	8	2	1	33	11	8	0	0	0	0	0	0	0	0	0.6	0	NR
Esso Petroleum (Montreal)	1983	56	3	3	44	3	2	11	0.8	0.8	11	0	0.8	0	0.8	0	0	14
B.P. (Anjou)	1983	0	0	0	0	0	0	0	0	0	0	0	0	40	4	1	0	0
Petro-Canada (Pointe-aux-Trembles)	1983	92	14	8	17	0	0	25	5	0.7	0	0	0	0	0.7	1	0	8
	1984	100	24	3	27	0.7	0	0	0	0	27	4	2	18	7	2	5	NR
Shell (Montreal)	1983	27	3	4	91	21	20	18	4	6	0	0	0	18	4	6	1	0
	1984	8	2	3	33	9	9	17	3	3	0	0	0	0	0	0	0	0
Ultramar (St-Romuald)	1983	67	21	13	8	3	3	0	0.7	0.7	0	0	0	33	11	6	11	83
	1984	0	0	0	0	3	0.6	0	0	1	0	0	0	25	4	0	0	100

M : monthly amount; O : one-day amount; N : maximum daily amount.
NR - not reported.

The refinery is subject to the guidelines and in 1983, Gulf was in compliance with the sulphide, ammonia nitrogen and toxicity limits. The company, however, frequently exceeded the limits for total suspended solids and oil and grease. Gulf stated that these high deposits of oil and grease were primarily due to excessive rainfall. Of the seven deposits that exceeded the monthly amounts, 40% exceeded the limits by less than 24%, 30% were between 25% and 50% above the limit and the remaining were less than 200% above the limit.

In 1983, Gulf was in compliance with the monthly amount 88% of the time and 97% with the daily limits. The annual deposits of total suspended solids were slightly above the limit; however, the deposits of the other parameters were significantly below the authorized levels. Gulf did not report 19% of the total number of tests requested; these were mainly due to pH, as 57% of the tests were not reported.

The 1984 performance improved slightly over 1983. The company was in compliance 92% of time with the monthly amounts, compared to 88% in 1983. The number of deposits in excess of the limits, however, was still high for total suspended solids and oil and grease. The reason given by Gulf for the high level of suspended solids was that they experienced operating problems with the secondary clarifier and had a loss of floating activated sludge. The 1984 annual deposits had decreased from those of 1983, except for total suspended solids which were still above the authorized level.

Esso Petroleum—Montreal. Esso has an activated sludge system and the treated effluent is sent to the St. Lawrence River. The company operated for nine months in 1983 and then ceased production. The refinery has since been mothballed.

During the operating period of 1983, Esso recorded non-compliance with the guidelines for all parameters except pH. The company had numerous deposits in excess of the monthly amounts, particularly for oil and grease (56% of the time not in compliance) and total suspended solids (33% of the time not in compliance). However, 70% of the deposits in excess of the monthly amounts were less than 24% above the limit.

In general, the refinery was in compliance with the monthly amounts 78% of the time, 99% with the one-day amount and 97% with the maximum daily amount. The annual deposits were all below the authorized levels with oil and grease being the closest to the limit. During its operation, 13% of the tests requested were not reported.

B.P.—Anjou. B.P. had a secondary treatment system (bio-filters) and discharged to the St. Lawrence River. The refinery discharged effluent for five months in 1983 and was permanently shut down in April 1983. The refinery is being decommissioned.

B.P. was in compliance for all parameters except ammonia nitrogen where it was not in compliance with the monthly amount 40% of the time.

B.P.'s annual deposits were all below the authorized level. The refinery provided the requested number of tests except for pH where only 42% of the requested tests were provided.

Petro-Canada—Pointe-aux-Trembles. This Petro-Canada refinery has a secondary treatment system consisting of bio-filters and a polishing pond. The combined treated effluent (from the refinery and adjacent petrochemical plant) is discharged into the St. Lawrence River.

Petro-Canada is subject to the guidelines. In 1983, the refinery experienced problems primarily with oil and grease, but excessive deposits were also reported for phenols, total suspended solids, toxicity and ammonia nitrogen. The monthly amount for oil and grease was exceeded 11 times out of 12. The daily limits for oil and grease were also exceeded. These large deposits of oil and grease were traced to problems with filtration and settling which also affected the proper removal of other contaminants. To correct these problems, new skimmers were added to the API separators, a fourth separator and fifth sand filter were installed, and a settling pond for backwash from the sand filters was constructed. The one failure of the toxicity test resulted from a spill of both phenols and caustic soda in the petrochemical wastewater.

The overall performance of Petro-Canada in 1983 was 73% of the time in compliance with the monthly amounts, and more than 96% of the time in compliance with the daily limits. Half of the monthly amounts exceeded the limits by less than 50% and most of the other half was between 50 and 100% above the limit. The annual deposits of oil and grease exceeded the authorized level by more than 50%. The deposits of the other parameters were all below the limits. Petro-Canada reported 96% of the requested tests.

In 1984, Petro-Canada continued to exceed the limits for oil and grease; deposits were above the monthly amount 100% of the time. The refinery also exceeded, to a lesser degree, the limits for sulphide, total suspended solids, ammonia nitrogen, and pH. Operating and maintenance problems with the acid gas scrubber caused the high deposits of sulphide and ammonia nitrogen.

The 1984 performance was 65% of the time in compliance with the monthly amounts, 93% and 97% for the one-day and the maximum daily amounts, respectively. The annual deposits increased since 1983 but were still below the limit except for oil and grease. The refinery has recently improved its performance at the request of the province and Environment Canada.

Shell--Montreal. The Shell refinery also has petrochemical processes. The combined effluent (from the refinery and the chemical plant) receives biological treatment (activated sludge) and is discharged into the St. Lawrence River.

Shell operates under the guidelines and was in compliance for only sulphide and toxicity in 1983. The pH level was exceeded very few times; a significant number of deposits for all other parameters were above the limits, especially total suspended solids. The oil and grease deposits were caused by problems with the separator and with oil emulsions in the desalter. Shell plans on introducing a polyelectrolyte in the dissolved air flotation unit to aid in the separation of emulsions. The total suspended solid discharges were the refinery's primary concern since the monthly amount was exceeded 91% of the time. The problem was caused by the high levels of oil and grease, which affected the biological treatment system, and by the overdesigned aeration basin. The oil in the effluent prevented the activated sludge from successfully forming large flocs which would allow the sludge to settle out and be recycled. Instead, the sludge was flushed out of the system creating the high level of suspended solids. The refinery also exceeded the monthly amounts for ammonia nitrogen and phenols. Problems with the operation of the sour water stripper caused the high levels of ammonia. The excessive deposits of phenols and pH were mainly caused by disturbances at the petrochemical plant.

The 1983 assessment of Shell was: 69% of the time in compliance with the monthly amounts; 93% of the time with the one-day amounts; and 94% of the time with the maximum daily amounts. Sixty percent of the deposits that were in excess of the monthly amounts were less than 50% above the limit and 35% were between 50 and 200% above the limit. The annual average of the total suspended solid discharges was significantly above the authorized level, and the deposits of the other parameters were below the limit. Shell provided all the requested tests.

In 1984, Shell was considered to be an expanded refinery and as such, had to meet limits equivalent to the more stringent regulation levels for the portion of RCR that was expanded. Despite that, the refinery had a better performance in 1984 than in 1983. The monthly amounts of oil and grease, total suspended solids, and phenols were still exceeded but the other parameters were not. The number of times the limits were exceeded is still high but this represents a significant improvement over the previous year. The majority of the 1984 annual deposits were lower than the 1983 deposits. This time the total suspended solids deposits were slightly above the authorized deposit; all the other parameters were still below the limit.

Ultramar—St. Romuald. Ultramar is subject to the guidelines. After the commissioning of a catalytic cracking unit, the refinery upgraded its wastewater treatment system by installing aerated lagoons. The system came on stream in late 1982. During the commissioning period, problems were identified and modifications made to correct them. The treated effluent is discharged into the St. Lawrence River.

Ultramar reported compliance for the sulphide parameter only. Most of the refinery's problems lay with the treatment of oil and grease (monthly amounts were exceeded 67% of the time). High oil and grease loadings to the biotreater hampered its performance. The installation of an additional air flotation unit to minimize the oil loadings was scheduled for 1985. The ammonia nitrogen level was also above the limits and the problem was traced to the sour water stripper. Corrective measures were introduced in the process to return the gas to the incinerator. The effluent also exceeded the limits for total suspended solids, pH level, and was toxic in five out of six tests. Problems with the sour water stripper were responsible for the high deposits.

In 1983, Ultramar was in compliance with the monthly amounts 78% of the time, 93% of the time with the one-day amounts and 89% with the maximum daily amounts. The majority of the monthly amount deposits exceeded the limit between 50% and 100%. The only annual average that was above the authorized deposit was oil and grease (44% above the limit). The company reported 95% of the requested tests.

In 1984 the performance improved, with ammonia nitrogen and toxicity being the only problems that remained. The ammonia nitrogen monthly amount was exceeded and the effluent was toxic to fish every time the test was performed (six times). The high ammonia nitrogen level was due to operating and maintenance problems of the acid gas scrubber. Most of the 1984 annual deposits were reduced from the 1983 level and they were all below the authorized deposits.

4.4.4 Ontario Region Assessment.

In 1983, eight refineries were operating in Ontario. One of them (Shell--Oakville) was decommissioned in July 1983. Six refineries were subject to the guidelines with three existing and three expanded. The other two were new refineries and were subject to the regulations. Esso in Sarnia, and Shell and Petrosar in Corunna are associated with petrochemical plants and treat a combined effluent (refinery and petrochemical) in the refinery's treatment system. In the case of the Esso refinery, the affiliated petrochemical plant has its own wastewater treatment system; but some of its effluent is treated by the refinery system. All the refineries in the region discharge treated effluent into part of the Great Lakes system which includes the St. Clair River, Lake Ontario, and Lake Erie. The individual refinery performance for 1983 is summarized in Appendix B.

In 1983, the region was in compliance with the monthly amounts 99% of the time. Six refineries, which included the new ones, were in compliance with the monthly amounts 100% of the time. The other two refineries: Gulf--Mississauga, and Shell--Corunna were in compliance 98% and 95% of the time, respectively. As illustrated in Figure 2, 57% of the deposits in excess of the monthly amounts were less than 25% above the limit and 86% were less than 99% above the limit. The region was also in compliance with the daily limits more than 99% of the time. Phenols and sulphide levels were never exceeded by any refinery. The two parameters that were most exceeded were total suspended solids, and oil and grease; however, the performance was still very good since compliance with the monthly amounts was 96% and 98% of the time, respectively, and more than 98% for the daily limits.

Regional performance in 1983 was much improved over that of 1980. For the monthly amount limits, the region was in compliance more than 99% of the time in 1983 compared to 96% in 1980. The number of deposits that exceeded the daily limits were also reduced in 1983. The performance in 1984 regressed, however, with only 94% of the time in compliance with the monthly amounts. The refineries that contributed most to this lower performance were: Gulf, Suncor and Shell.

The annual averages of deposits in the region from 1972 to 1984 are presented in Figures 29 to 33. The actual deposits in 1983 decreased since 1980 for all the parameters. In general, the 1984 levels were also lower than those of 1983, except for oil and grease which was still below the limit. All the annual discharges since 1980 were below the limits.

As shown in Figures 34 to 38, the 1983 average deposits were below the limits for every parameter at all the refineries. Comparing the performance of each refinery shows that: Texaco and Petro-Canada had the lowest discharge of oil and grease and Gulf had the highest; Texaco had the lowest level of total suspended solids and Esso had the highest; all the refineries had very low levels of phenols and ammonia nitrogen; however, Texaco had the best performance for phenols and Shell--Corunna for ammonia; the sulphide discharges were also very low for all the refineries except Petro-Canada which had the highest level.

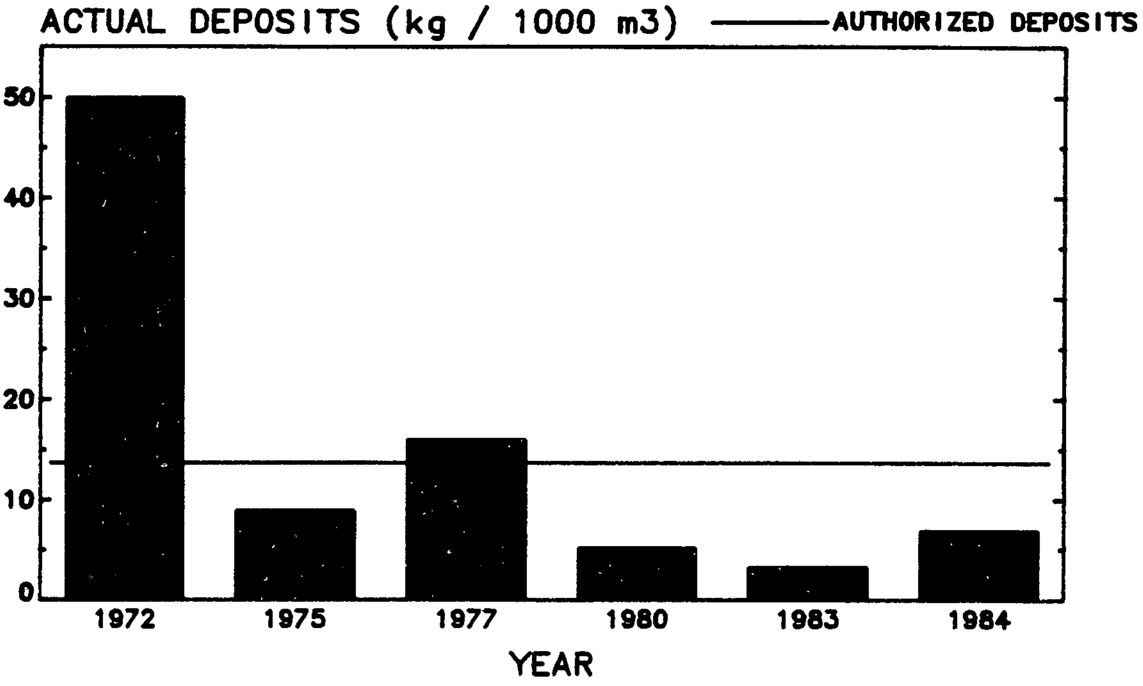


FIGURE 29 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Ontario Region - 1972 to 1984)

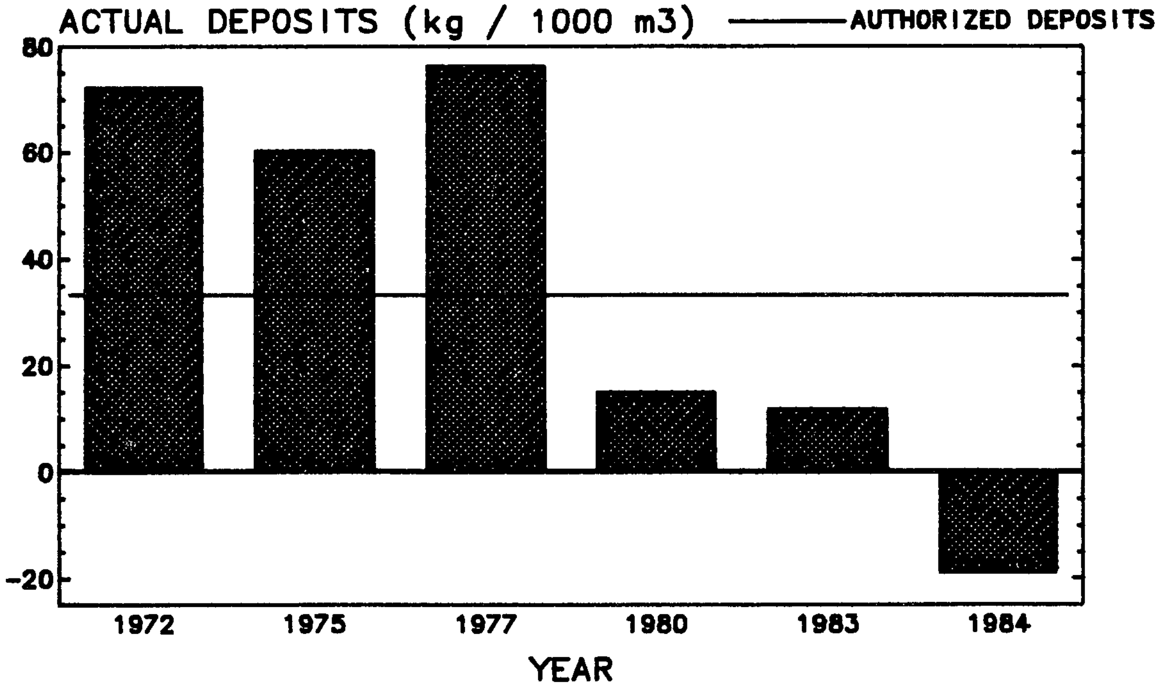


FIGURE 30 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Ontario Region - 1972 to 1984)

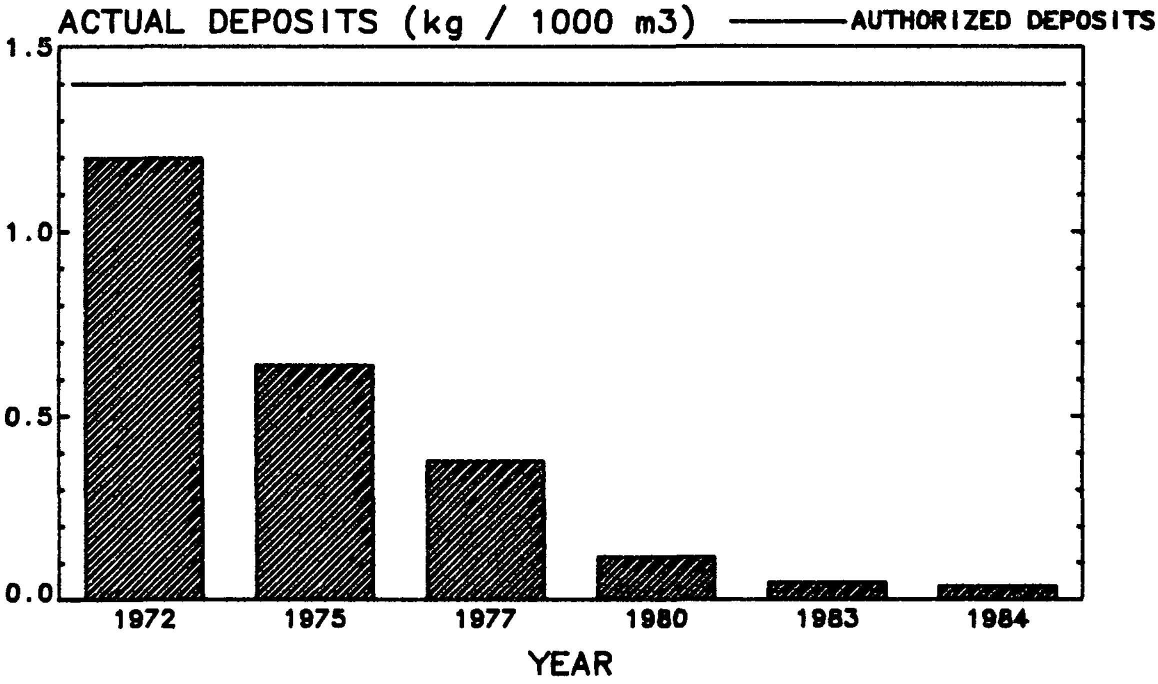


FIGURE 31 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Ontario Region - 1972 to 1984)

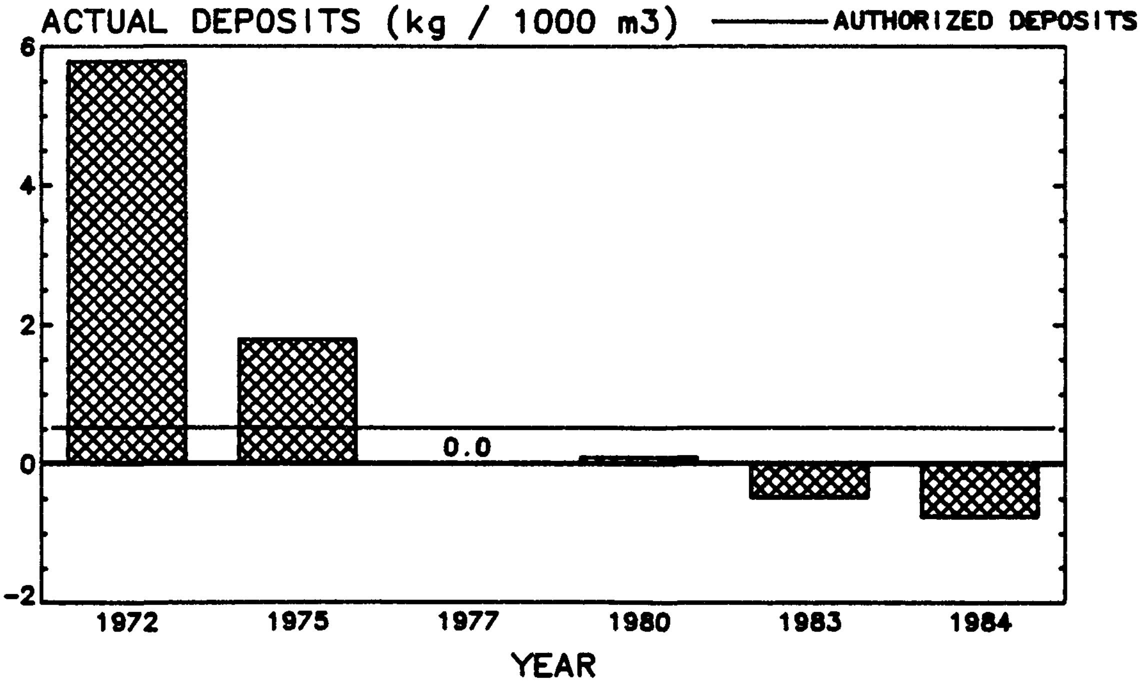


FIGURE 32 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Ontario Region - 1972 to 1984)

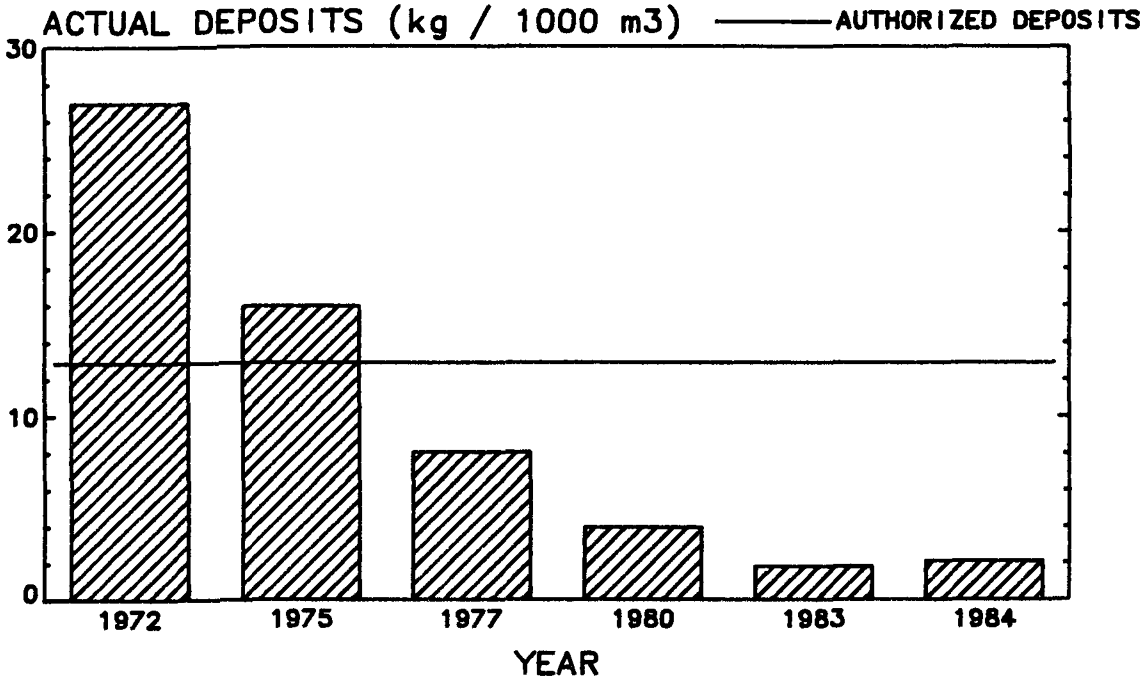


FIGURE 33 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Ontario Region - 1972 to 1984)

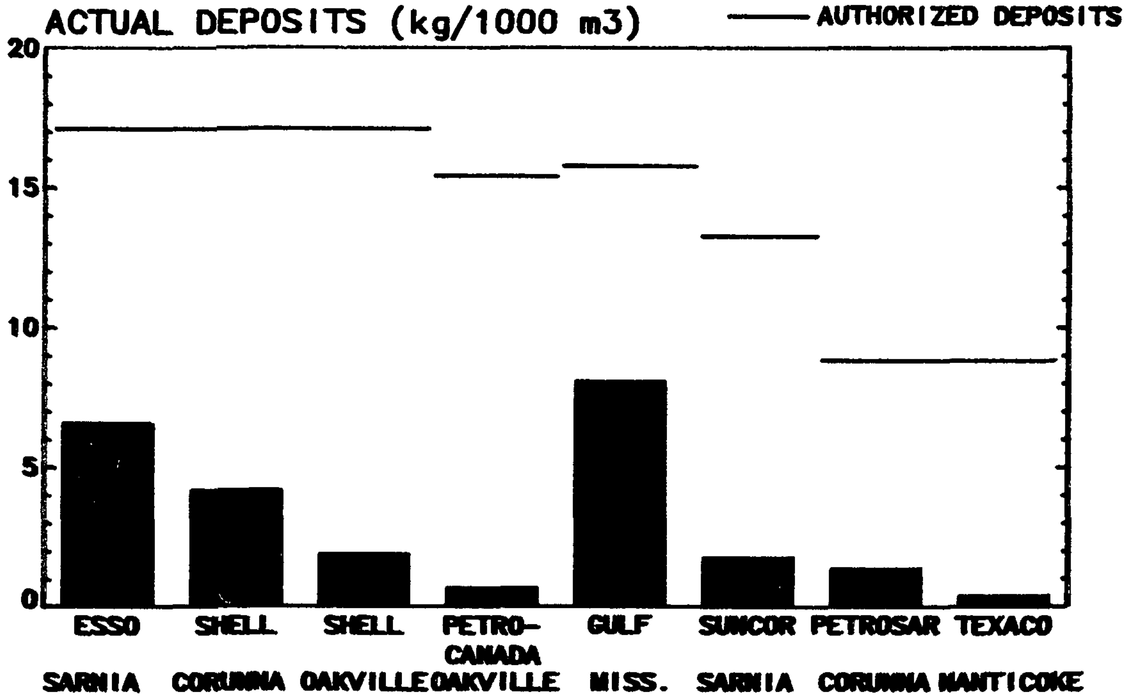


FIGURE 34 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Ontario Region - 1983)

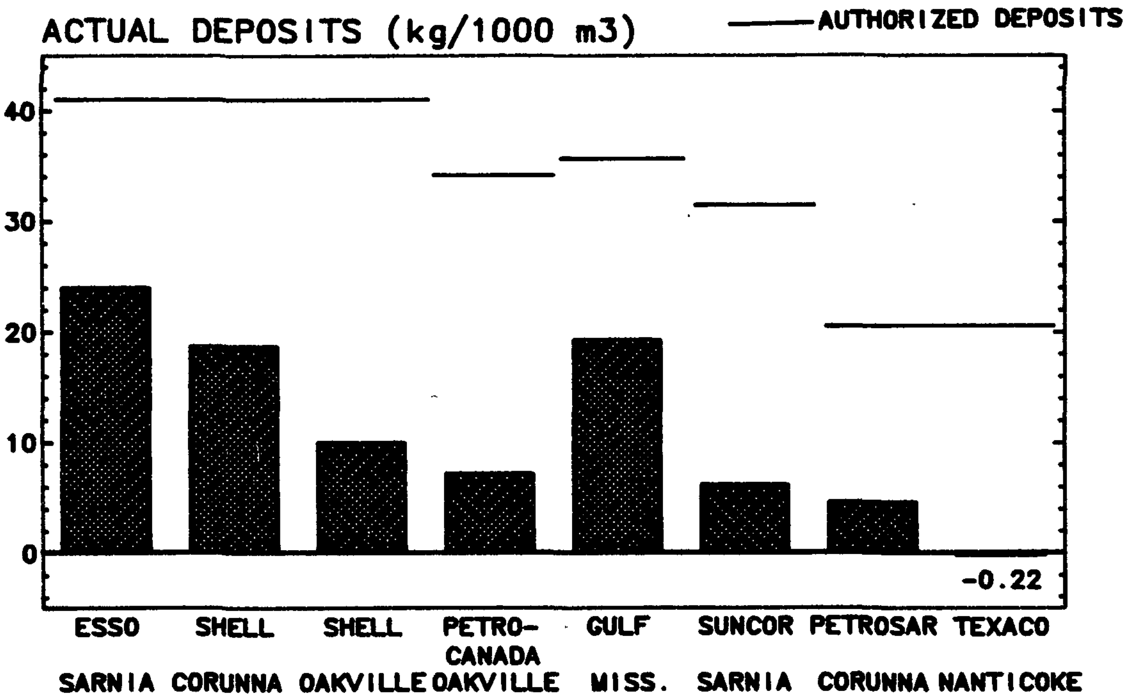


FIGURE 35 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Ontario Region - 1983)

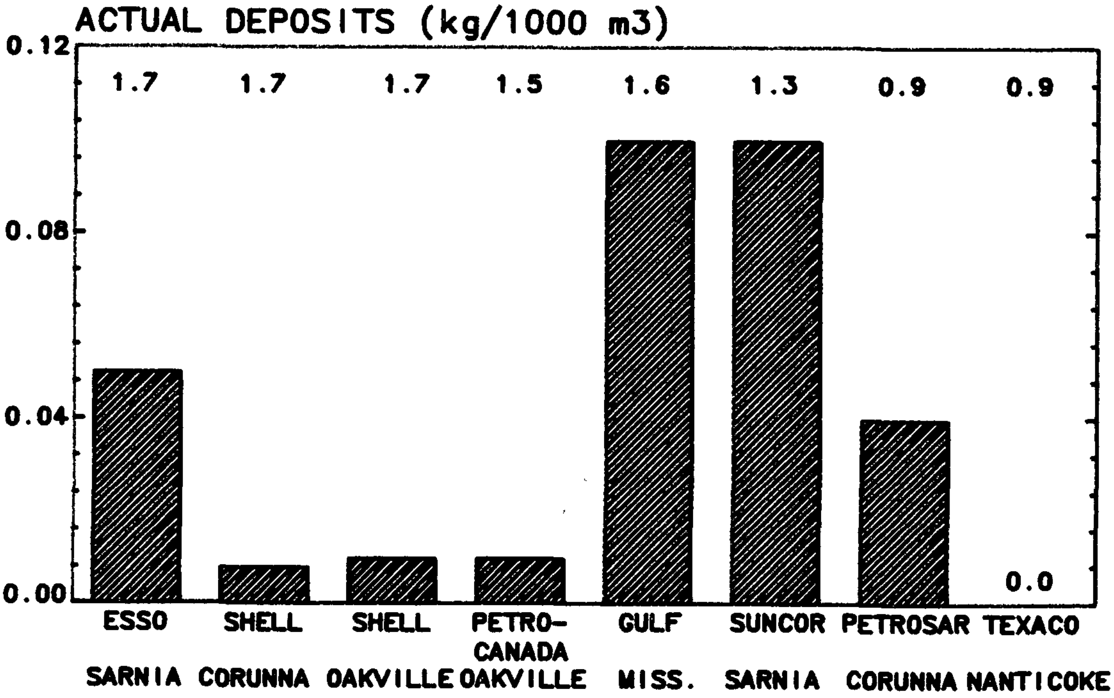


FIGURE 36 PHENOLS DISCHARGE LEVELS BY REFINERY (Ontario Region - 1983)

(NUMBERS AT TOP OF CHART REPRESENT AUTHORIZED DEPOSITS)

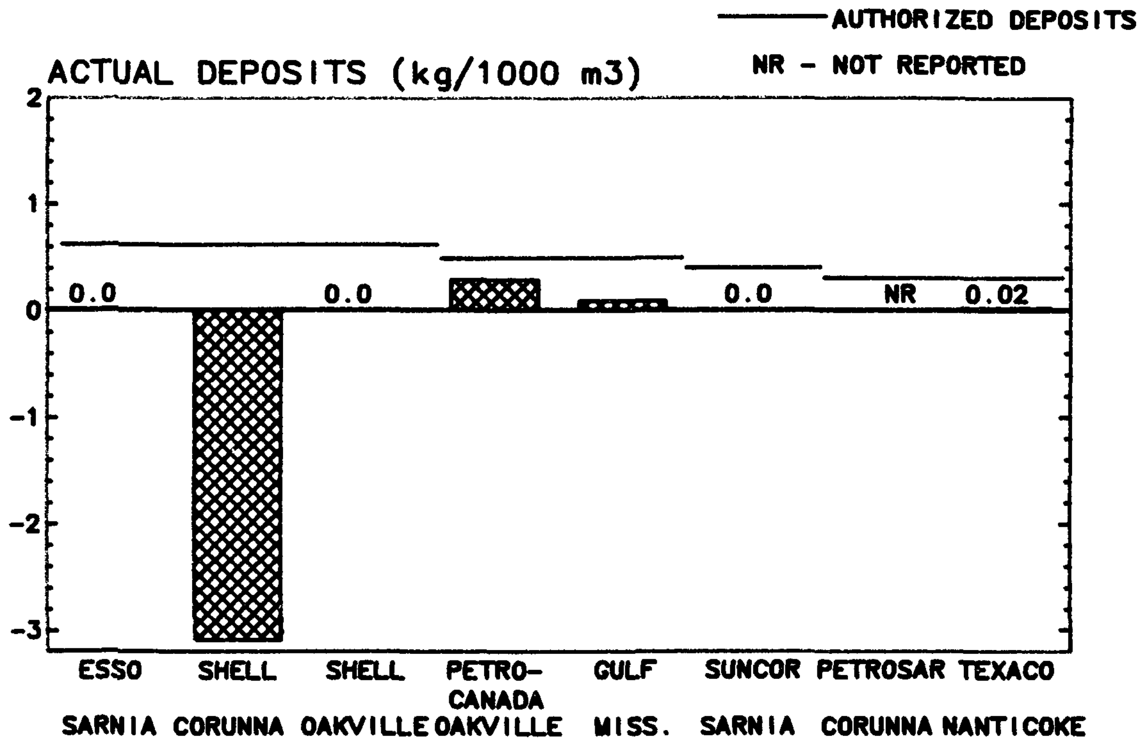


FIGURE 37 SULPHIDE DISCHARGE LEVELS BY REFINERY (Ontario Region - 1983)

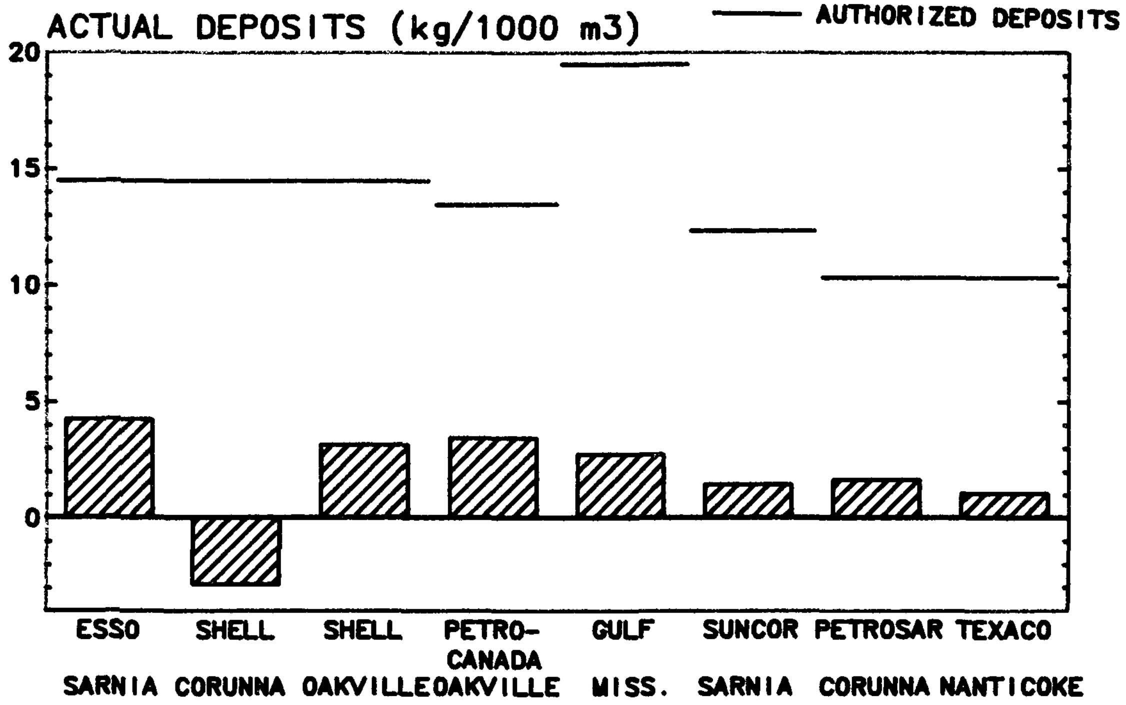


FIGURE 38 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY (Ontario Region - 1983)

The two refineries that are subject to the regulations both had a very good performance in 1983 with only three violations of the maximum daily amount for Petrosar and two also for Texaco. These violations represent 0.1% of the time. The 1984 performance was even better with Petrosar being in compliance 100% of the time for all the parameters and Texaco having only one violation of the pH level. However, Petrosar violated the monitoring requirements by not testing for sulphide deposits for 1983 and 1984. This resulted from an agreement made with the Ontario Ministry of the Environment. In 1985, however, Petrosar reinstated sulphide testing. The annual deposits of these refineries were all very low for 1983 and 1984 compared to the authorized levels.

In the Sarnia area, total suspended solids are highly variable in the intake water. Solids appear to be trapped in cooling water systems and subsequently flushed out days later leading to numerous deposits that exceed the daily suspended solids limit. The situation was discussed in 1983 and it was decided that the refineries in this area (Esso Petroleum, Petrosar, Shell and Suncor) would be granted the option of assessing total suspended solids only in process water and stormwater for the purpose of determining compliance with the federal regulations and guidelines, while cooling water would be exempted. This option was used to assess Esso, Shell (Corunna) and Suncor. Petrosar uses cooling towers and does not discharge once-through cooling water.

Eleven percent of the tests required were not reported in 1983 and 12% in 1984, mostly for sulphide. The regional crude production was reduced in 1983 by 19% of the 1980 level. The production was further reduced by 3% in 1984 compared to the 1983 level. The reduction was caused by the shut down of Shell--Oakville. The performance of each refinery in this region is presented in Table 28 giving 1983 and 1984 values for each parameter.

Esso Petroleum--Sarnia. This refinery is closely affiliated with a chemical plant, Esso Chemical Canada. Although each facility has its own wastewater treatment system, some effluent from the chemical plant is treated in the refinery system. In addition, the chemical plant manufactures crude-based BTX (benzene, toluene and xylene) which is considered as a "refinery" product, and the generated effluent is treated at the chemical plant's system. As in the past, only the effluent that was treated at the refinery was considered for the 1983 compliance assessment. The refinery has a biological treatment system (activated sludge process) and discharges its effluent into the St. Clair River.

TABLE 28 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Ontario Region - 1983, 1984)

		% of time not in compliance																			
		Oil and Grease				Total Suspended Solids				Phenols				Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery		M	O	N	S	M	O	N	S	M	O	N	S	M	O	N	M	O	N	N	N
Esso	1983	0	0	0.3		0	0	0		0	0	0		0	0	0	0	0.6	2	0	0
(Sarnia)	1984	17	6	8		8	0	2		0	0	0		0	0	0	0	0	0.6	0	0
Shell	1983	8	0.4	0.4		17	0	10		0	0	0		0	0	0	0	0	0	0.3	0
(Corunna)	1984	8	3	4		42	11	23		0	0	0		0	0	0	0	0	0	0	0
Shell (Oakville)	1983	0	0	0		0	0	0		0	0	0		0	0	0	0	0	0	0	0
Petro-Canada	1983	0	0	0		0	0	0		0	0	0		0	0	0	0	0	0	0	8
(Oakville)	1984	0	0	0		0	0	0		0	0	0		0	0	0	0	0	0	0	0
Gulf	1983	0	1.7	3	25	8	2	2	0	0	0	0	0	0	0	0	0	0	0	0.8	0
(Mississauga)	1984	58	42	33	25	17	23	20	0	0	0	0.6	0	0	0	0.6	8	12	8	0	8
Suncor	1983	0	0	0.4		0	3	3		0	0	0		0	0	0	0	0	0	0	0
(Sarnia)	1984	8	0.7	1		42	20	15		0	0	0		17	0	0.6	0	0	0	0	0
Petrosar	1983	0	0	0.3		0	0	0.3		0	0	0		NM	NM	NM	0	0	0	0.3	0
(Corunna)	1984	0	0	0		0	0	0		0	0	0		NM	NM	NM	0	0	0	0	0
Texaco	1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0
(Nanticoke)	1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0

M : monthly amount; O : one-day amount; N : maximum daily amount; S : stormwater limits
NM : not measured

Esso is subject to the guidelines and was in compliance in 1983 with the limits for most parameters. A few deposits exceeded the daily limits of ammonia nitrogen, and oil and grease. All the annual deposits were distinctly below the limits. Esso reported almost all of the tests requested.

In 1984, the refinery experienced some problems with oil and grease and with total suspended solids. An oil heavier than water entered the sewer system and could not be removed by the API separator. This was responsible for the two deposits that exceeded the oil and grease monthly amount. There was also one monthly amount that exceeded the limit for suspended solids. This was attributed to the low level of porous media in the dual-media filters. Measures have been taken to correct these problems. The annual deposits for all parameters were still below the limits in 1984.

Shell—Corunna. A biological oxidation unit (activated sludge) is used at this refinery to treat the refinery effluent along with the effluent from an associated chemical plant. Effluent is then discharged into the Talfourd Creek (to the St. Clair River).

In 1983, Shell exceeded the monthly amounts set in the guidelines twice for total suspended solids and once for oil and grease. The suspended solid deposits were attributed mainly to carryover from the west clarifier when it was undergoing repairs. The five deposits that exceeded the maximum amount limit for suspended solids were often caused by heavy rains and subsequent runoff. The oil and grease problem was short-lived and it is suspected that contaminated sample bottles may have been the cause.

The overall performance in 1983 was: 95% of the time in compliance with the monthly amounts and more than 98% with the daily limits. Of the three monthly amounts that exceeded the limit, one was more than 400% above the authorized level and the other two were less than 50% above the limit. Negative annual average discharges were calculated in 1983 for sulphide and ammonia nitrogen. The negative averages were due to the highly variable nature of the upstream intake water which was often higher in concentration than the effluent. The annual deposits were below the limit for all parameters. The refinery reported only 71% of the requested tests. Very few measurements of total suspended solids, sulphide and ammonia nitrogen, or toxicity test results were reported (less than 34% of the requested tests).

In 1984, the refinery exceeded the total suspended solids and the oil and grease limits more frequently. All the other parameters were in compliance. Five monthly amounts exceeded the suspended solids limit and one exceeded the oil and grease limit. In general, the refinery was in compliance with the monthly amounts 90% of the time, 97.5% with the one-day amounts, and 96.5% with the maximum daily amounts. The overall performance of 1984 was not as good as that of 1983. The annual deposit of oil and grease and phenols increased in 1984 but remained below the authorized deposit. The discharges for the other parameters were negative and smaller than the 1983 deposits.

Shell--Oakville. The Oakville refinery operated for only six months in 1983 and was permanently shut down on July 2, 1983. The refinery had a biological treatment system and discharged the effluent into Lake Ontario.

The refinery was in complete compliance with the guidelines for all the parameters. Shell reported all the requested tests except pH where 57% of the tests were not reported.

Petro-Canada--Oakville. This Petro-Canada refinery has an activated sludge process and discharges the effluent into Lake Ontario. Petro-Canada has an expanded status under the guidelines.

The refinery was in compliance in 1983 with all the limits except for one toxicity test that had a 65% fish mortality. The chief reason for the toxicity of the effluent was an increase in sulphide levels in the process water, leading to reduced biological oxidation efficiencies because of sulphide toxicity. Measures were taken to improve the sulphide collection system and the aerobic capacity of the process. Changes made to the wastewater treatment system included replacement of the flocculation/primary clarifier units and replacement of coarse air diffusers in the existing aeration tanks.

The 1983 average annual deposits were all very low compared to the authorized limits. The refinery reported all the requested tests except for pH where 27% of the tests were not reported.

The performance in 1984 was excellent and the refinery was always in compliance for all the parameters. The annual deposits in 1984 were comparable to the 1983 values.

Gulf--Mississauga. The Gulf refinery treats its process and ballast water with an activated sludge system. The treated effluent is then discharged into Lake Ontario. After primary treatment, the high strength phenolic water is discharged into the Mississauga municipal sewage treatment plant.

In 1983, the refinery had an expanded status under the guidelines and was in complete compliance for phenols, sulphide, ammonia nitrogen and toxicity. However, high levels of total suspended solids, oil and grease, and pH were deposited. The high amounts of suspended solids were caused mainly by an emulsion in the oily water separator. Gulf exceeded the pH limit less than 1% of the time and the cause was excessive injection of phosphoric acid. The oil and grease monthly limit for stormwater was exceeded 25% of the time. A new floating skimmer installed on the stormwater holding pond resulted in improved stormwater quality compared to previous years, but further changes or more careful operation may be required to prevent future problems.

Gulf was in compliance with the monthly amounts during 1983 more than 98% of the time, 99% with the daily limits, and 92% with the stormwater monthly limits. Three-quarters of the monthly amount and the stormwater deposits that exceeded the limits were less than 24% above the limit. The other 25% was between 50 and 100% above the limit. The annual deposits in 1983 were clearly below the limits for all the parameters. Gulf reported more tests than any other refinery in the region. Only 1.4% of the pH measurements were not reported.

In 1984, the refinery had an existing status and was therefore subject to less stringent limits than in 1983. The effluent quality in 1984, however, was clearly lower than that of 1983. Monthly amounts for oil and grease were exceeded 58% of the time, and total suspended solids and ammonia nitrogen monthly amounts were also exceeded. In addition, numerous deposits exceeded the daily limits for these three parameters. Deposits exceeded the daily limits for the other parameters less frequently. One of the reasons for the high deposits of oil and grease and suspended solids was the maintenance shutdown of some equipment at the wastewater treatment plant. The equipment included the sand filtration unit air compressor, the sand filter backwash clarifier, one sand filter, and a steam coil in the slop tank. The other reason was that the refinery experienced process operating problems which adversely affected the treatment plant. Frequent upsets occurred in the crude desalter unit and problems arose in handling the plant slop oil. When the hydrofluoric acid alkylation plant was permanently shut down and the plant was neutralized with ammonia, some solution found its way into the effluent and was responsible for the high ammonia discharges. All these problems resulted in high annual deposits in 1984, especially for oil and grease where the deposit exceeded the limit by more than 40%. The other parameters were all below the limits but were higher than those of 1983.

Suncor--Sarnia. This Suncor refinery treats its wastewater in a secondary treatment system and discharges the effluent into the St. Clair River. Suncor is subject to the guidelines and had an expanded status for 1983 and 1984.

The refinery was in compliance in 1983 for phenols, sulphide, ammonia nitrogen, pH and toxicity. Very few high daily deposits occurred for oil and grease; some deposits exceeded the daily suspended solids limits.

The overall performance of Suncor was very good in 1983. The refinery was 100% in compliance with the monthly amounts and more than 99% in compliance for the other two daily limits. The 1983 annual deposits were all very low compared to the authorized levels. The refinery did not report enough tests for sulphide (74% were not reported) or for pH (28% were not reported); all the requested tests were reported for the other parameters.

The 1984 performance was not as good. The refinery exceeded the monthly amounts for total suspended solids (42% of the time), sulphide, and oil and grease. The daily limits were also exceeded for these parameters. The installation of a new hydrocracker unit was responsible for most of these high deposits. Another factor that contributed to the high levels of oil and grease was an analytical error introduced in the measurements. In total, Suncor was in compliance 87% of the time with the monthly amounts and 98% with the daily limits. All the 1984 annual deposits were higher than the 1983 values but were still below the limits.

Petrosar—Corunna. Petrosar is a new refinery and was, therefore, subject to the regulations. The refinery also has petrochemical processes and treated both effluents in the same system which consisted of a biological oxidation unit followed by a tertiary system (activated carbon filters). The effluent is then discharged into the St. Clair River.

In 1983, the refinery was essentially in compliance 100% of the time, recording only three deposits that exceeded the maximum daily amount (one each for oil and grease, total suspended solids and pH level). No violations occurred for the other parameters. Sulphide, however, has not been monitored by Petrosar since 1979 as a result of an agreement with the Ontario Ministry of the Environment. Environment Canada would like to see occasional sulphide monitoring reinstated to confirm that sulphide continues to be undetected by the regulatory test method. In addition, the refinery did not report 7% of the pH measurements. A high pH level was caused by control problems of the equalization pits.

During 1983, the biological treatment system was improved. Air spargers and mixers were installed in the base of the aeration tanks to supply additional oxygen and mixing.

Petrosar modified the methodology used for calculating net loadings of pollutants. Previously, the net loadings were based on the difference between intake and effluent concentrations. This was valid only when intake and effluent volumes were the same. Petrosar recycles its water, however, and a significant amount is lost by evaporation in the cooling towers. For 1983 (and 1984), the gross intake loading was subtracted from the gross effluent loading to arrive at the net load to the river.

The 1983 annual deposits were well below the authorized levels. The 1984 deposits were even lower. Petrosar had an excellent performance in 1984, the monthly and daily discharges of all parameters were 100% in compliance with the regulations. However, the refinery did not report any sulphide tests, which is in violation of the reporting requirements. In 1985, Petrosar reinstated sulphide testing.

Texaco--Nanticoke. Texaco in Nanticoke is a new refinery and was subject to the regulations. The refinery has an activated sludge unit followed by a tertiary treatment consisting of an effluent filtration unit. The treated effluent is discharged into Lake Erie.

During 1983, Texaco was in complete compliance for all parameters with the exception of two violations of the pH level. These may be attributed to alkaline wastewaters which were discharged from the alkylation unit. A negative annual average deposit was calculated for total suspended solids. This was due to the high variation of suspended solids upstream, which were often higher in the intake than in the effluent. All the annual deposits were very low compared to the authorized levels. The company reported almost all of the requested tests.

In 1984, the performance was better than 1983, with only one violation of the pH level. The annual average of deposits were also lower in 1984. The refinery provided all the tests that were required except for pH where only 4% was not reported.

4.4.5 **Western & Northern Region Assessment.** Eight refineries in the Western & Northern region were subject to the guidelines and two of these refineries had an expanded status. In addition, the region now has four new refineries (Turbo, Husky and Esso in Edmonton, and Shell in Scotford, which came on stream in September 1984). New refineries must comply with the more stringent regulation limits. Husky built a new refinery adjacent to its old one in Lloydminster bringing it on-line in May 1983. However, the refinery was not assessed because its effluent is deep-well injected. In Alberta, the provincial requirements for an effluent that is deep-well injected are stricter than the federal effluent regulations and guidelines. The old Husky refinery was decommissioned in March 1983. The Shell refinery in Winnipeg was shut down in October 1983; Gulf in Calgary in December, 1983; and Texaco in Edmonton in May, 1984. The effluents from three refineries (Gulf--Moose Jaw; Shell--Winnipeg; and Co-op--Regina) are further treated off-site at municipal facilities. Shell--Bowden did not discharge any effluent in 1983 and 1984. The individual performances for 1983 are presented in Appendix B.

In 1983, on average, the region was in compliance with the monthly amounts of the guidelines 89% of the time, and of the regulations, 94% of the time. The refineries subject to the guidelines had the most difficulty with ammonia nitrogen and total suspended solids. The refineries subject to the regulations had problems with sulphide and, to a lesser degree, oil and grease. Three refineries (Gulf--Edmonton; Texaco--Edmonton; and Gulf--Calgary) were in compliance with the guideline monthly amounts 100% of the time. The following refineries had the lowest performance with respect to the monthly amounts: Co-op, in compliance only 55% of the time; Esso--Norman Wells, in compliance 63% of the time; and Shell--Winnipeg, in compliance 75% of the time. As shown in Figure 2, 43% of the deposits that exceeded the monthly amounts were more than 200% above the limit. The region was also in compliance 96% of the time with the one-day amounts and 98% of the time with the maximum daily amounts.

Compared to 1980, the 1983 regional performance regressed. More deposits exceeded the monthly amounts and annual deposits were larger for most of the parameters. The daily limits, however, were exceeded less frequently in 1983. In 1984, the situation improved and the region was in compliance with the monthly amounts more than 92% of the time.

The regional annual deposits from 1972 to 1984 are presented in Figures 39 to 43. As shown in these figures, most of the 1983 discharge levels increased compared to those of 1980. The levels were still below the authorized limits except for sulphide where the deposits were more than twice the allowable limit. The Co-op refinery in Regina was responsible for most of the regional deposits of sulphide. The 1984 discharge levels were reduced from those of 1983, but were still higher than the 1980 levels. Sulphide was the only parameter that was above the 1984 authorized deposit.

The annual deposits for all the refineries in the region in 1983 are presented in Figures 44 to 48. A minimum of one refinery was over the authorized deposit for each parameter. For oil and grease, Esso--Norman Wells was above the limit and, Gulf--Edmonton and Turbo had the lowest discharges. Although the total suspended solids limit was exceeded by Esso--Norman Wells, the high levels present in the Mackenzie River (used for intake water) were responsible for this. Turbo, Gulf--Edmonton and

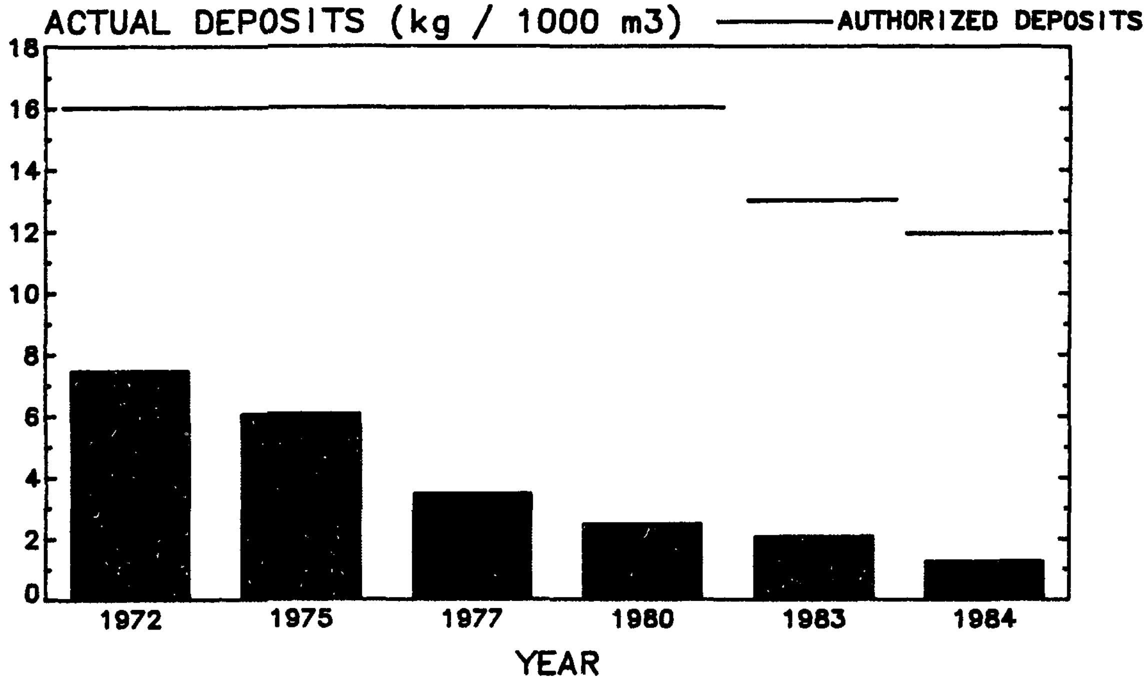


FIGURE 39 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Western & Northern Region - 1972 to 1984)

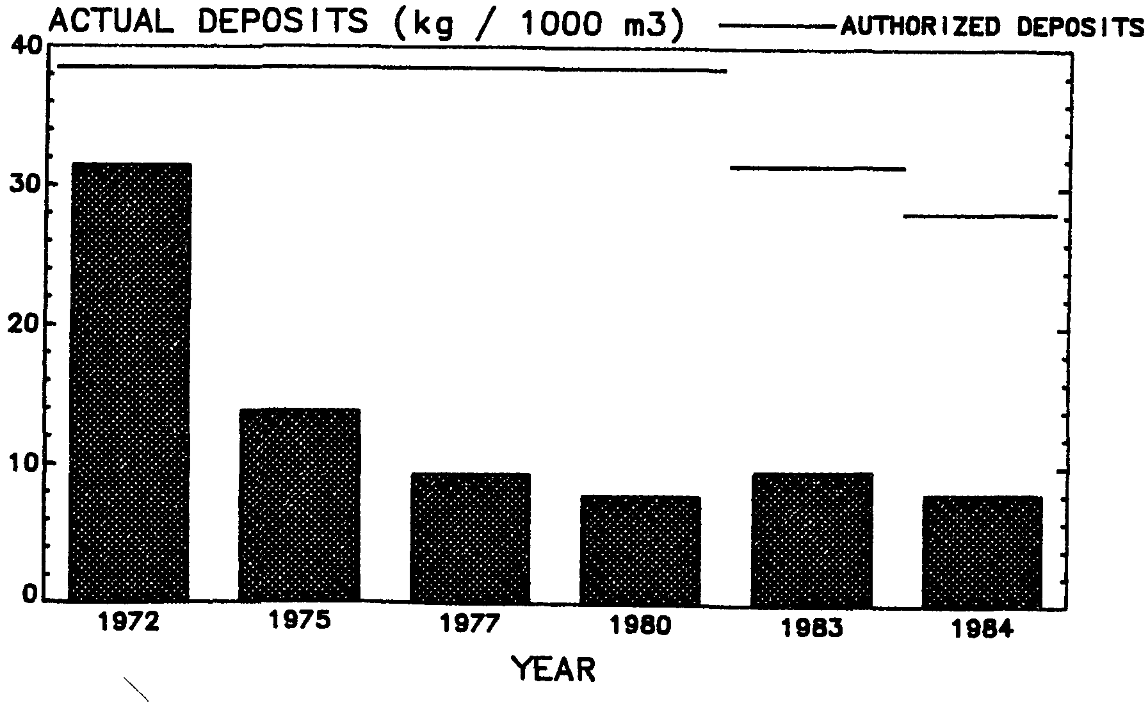


FIGURE 40 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Western & Northern Region - 1972 to 1984)

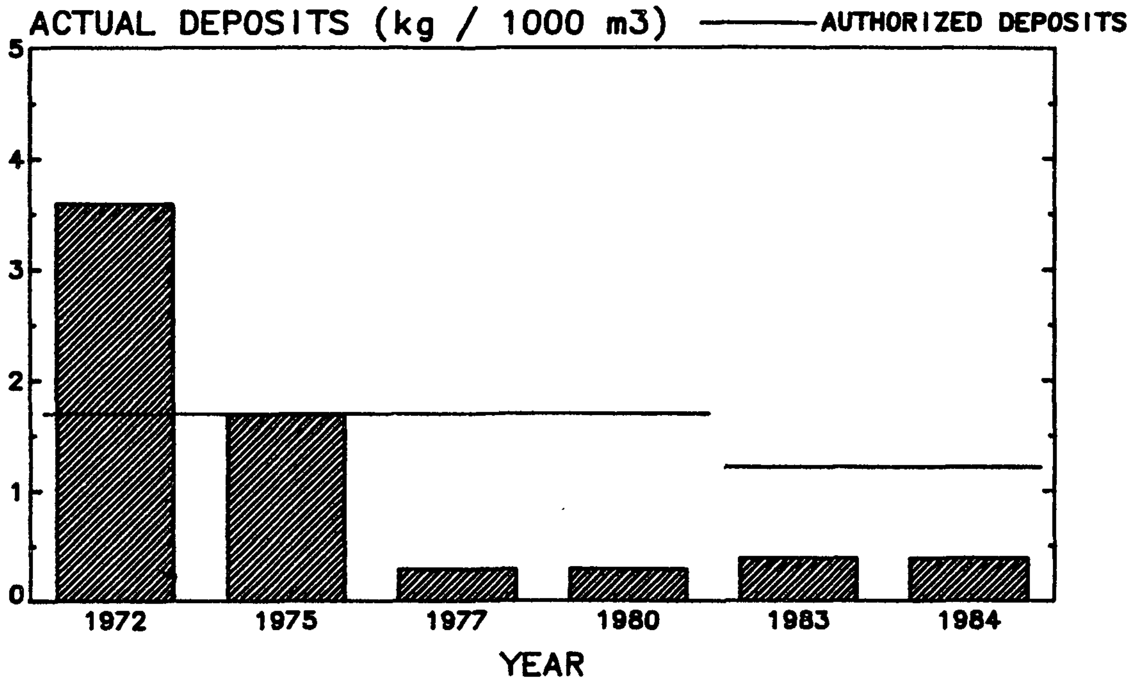


FIGURE 41 AVERAGE ANNUAL DISCHARGES OF PHENOLS
(Western & Northern Region - 1972 to 1984)

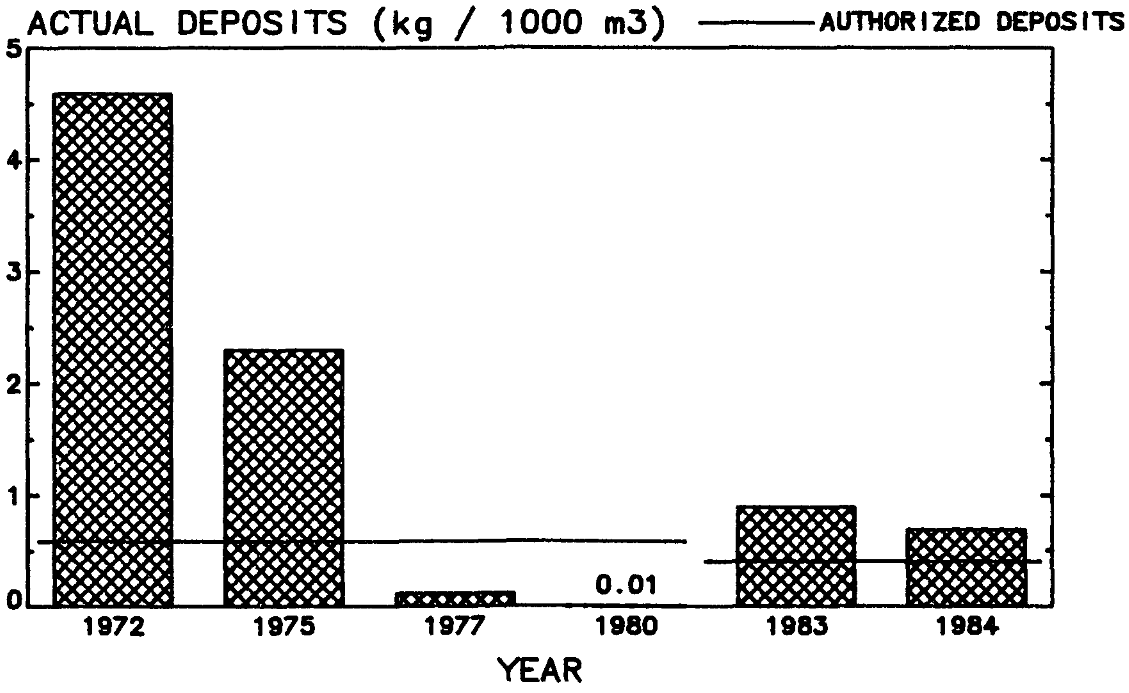


FIGURE 42 AVERAGE ANNUAL DISCHARGES OF SULPHIDE
(Western & Northern Region - 1972 to 1984)

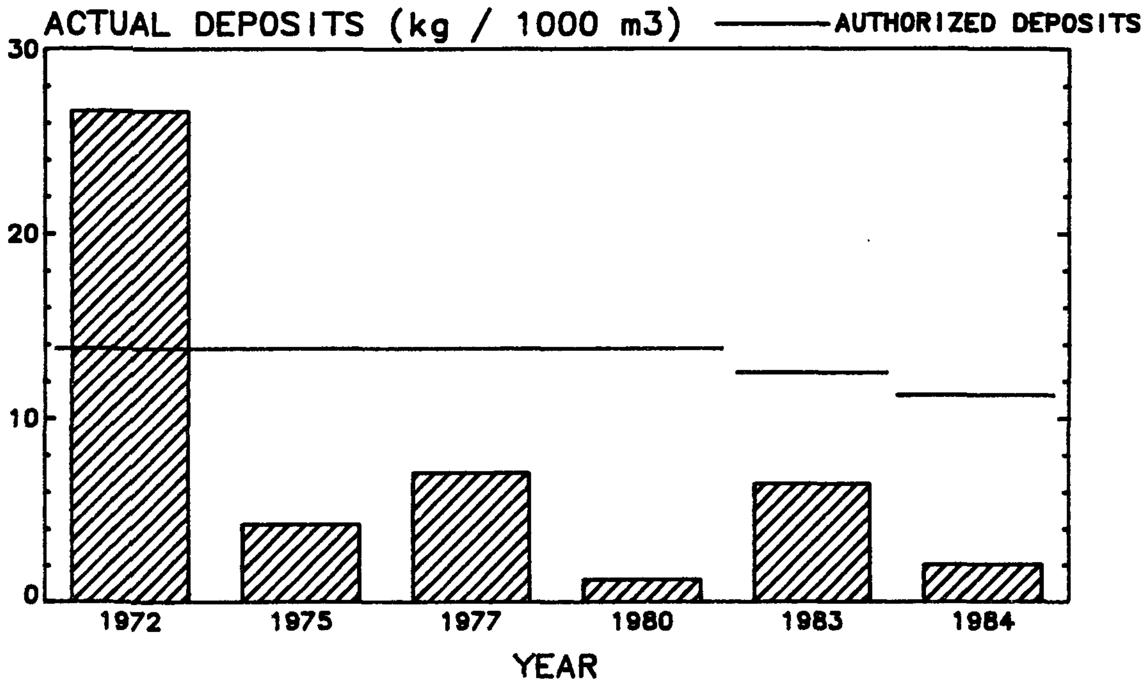


FIGURE 43 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Western & Northern Region - 1972 to 1984)

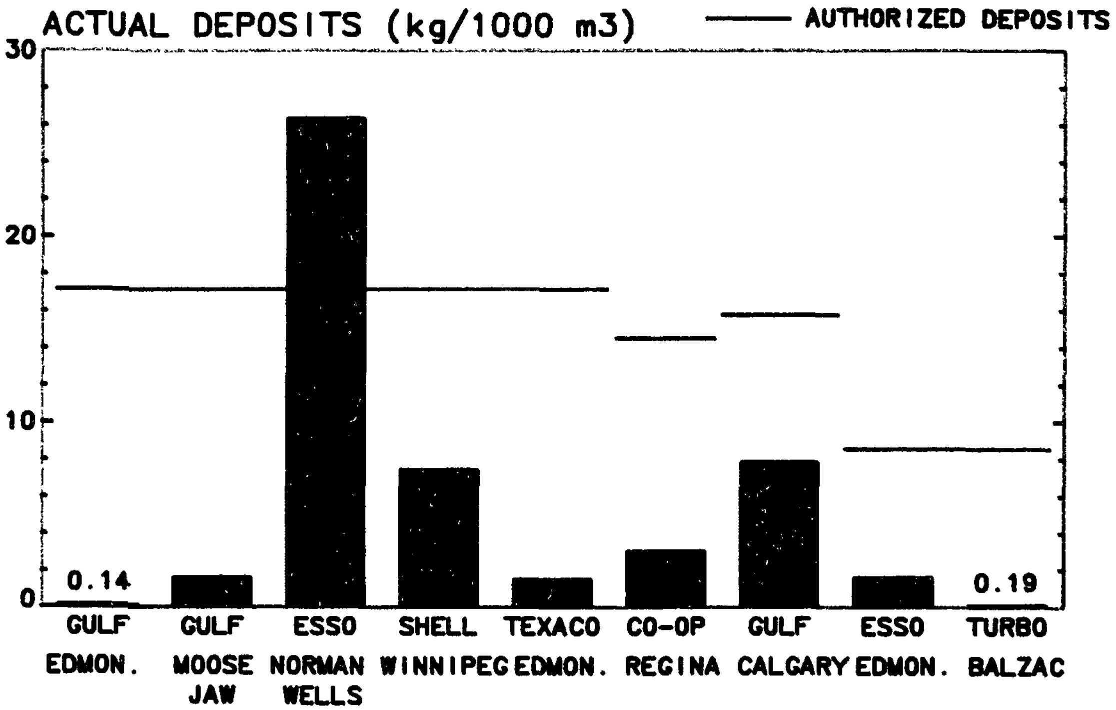


FIGURE 44 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1983)

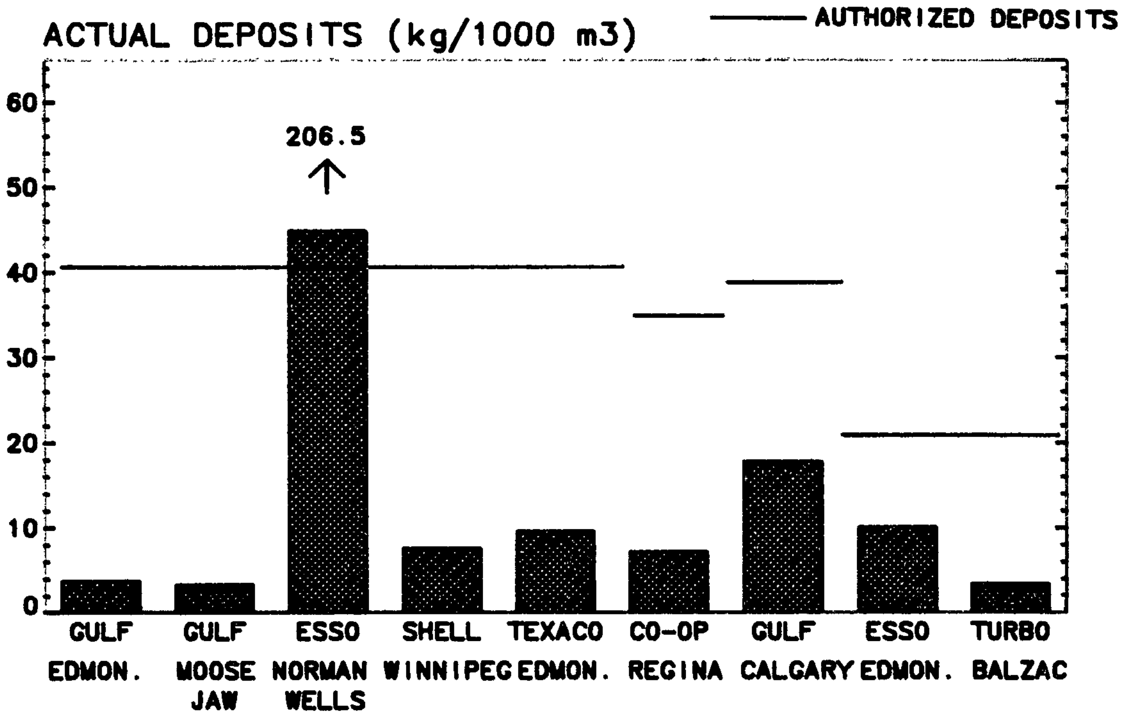


FIGURE 45 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1983)

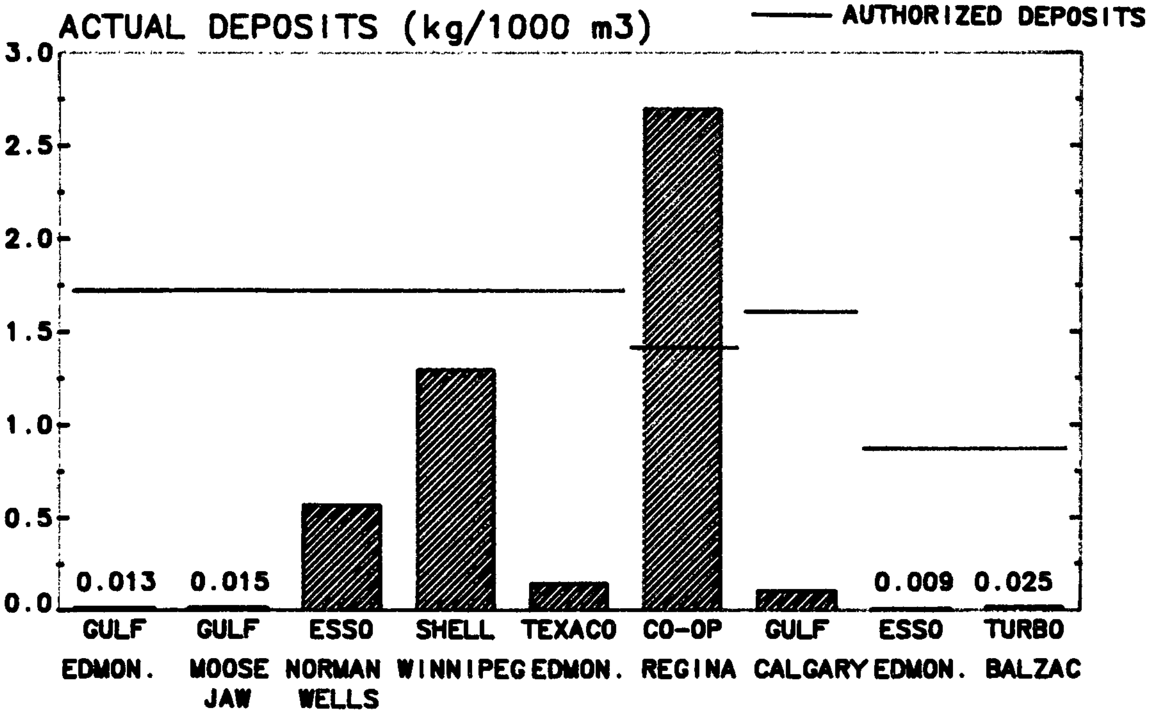


FIGURE 46 PHENOLS DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1983)

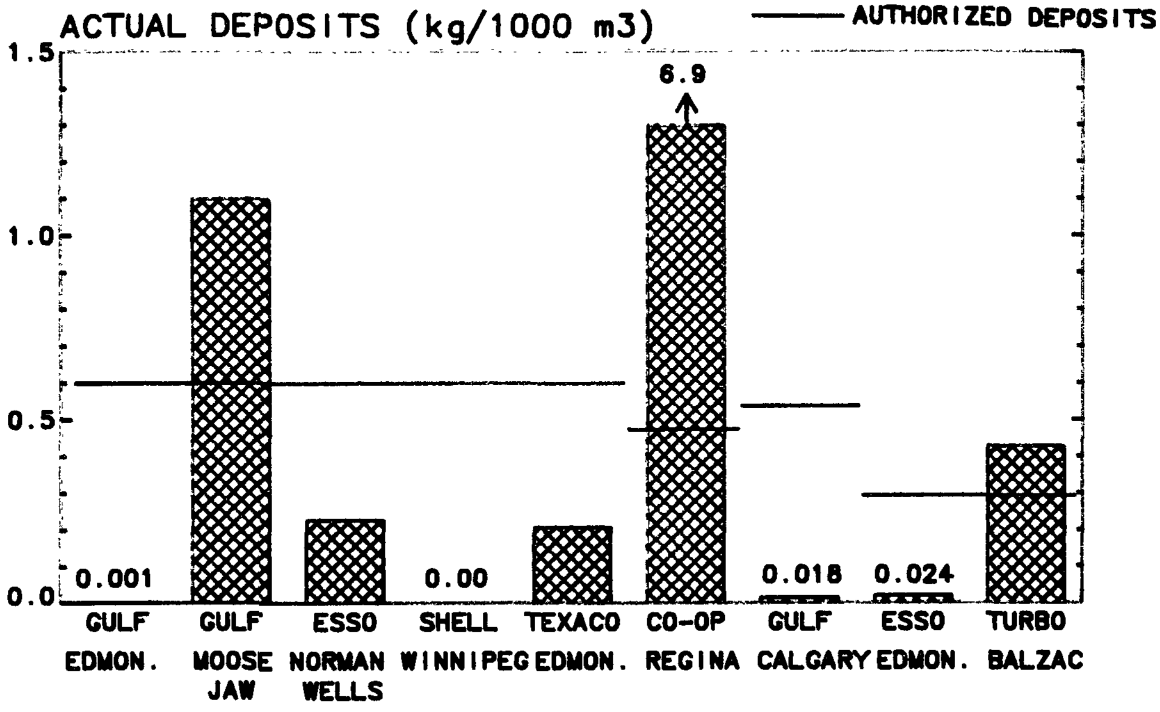


FIGURE 47 SULPHIDE DISCHARGE LEVELS BY REFINERY
(Western & Northern Region - 1983)

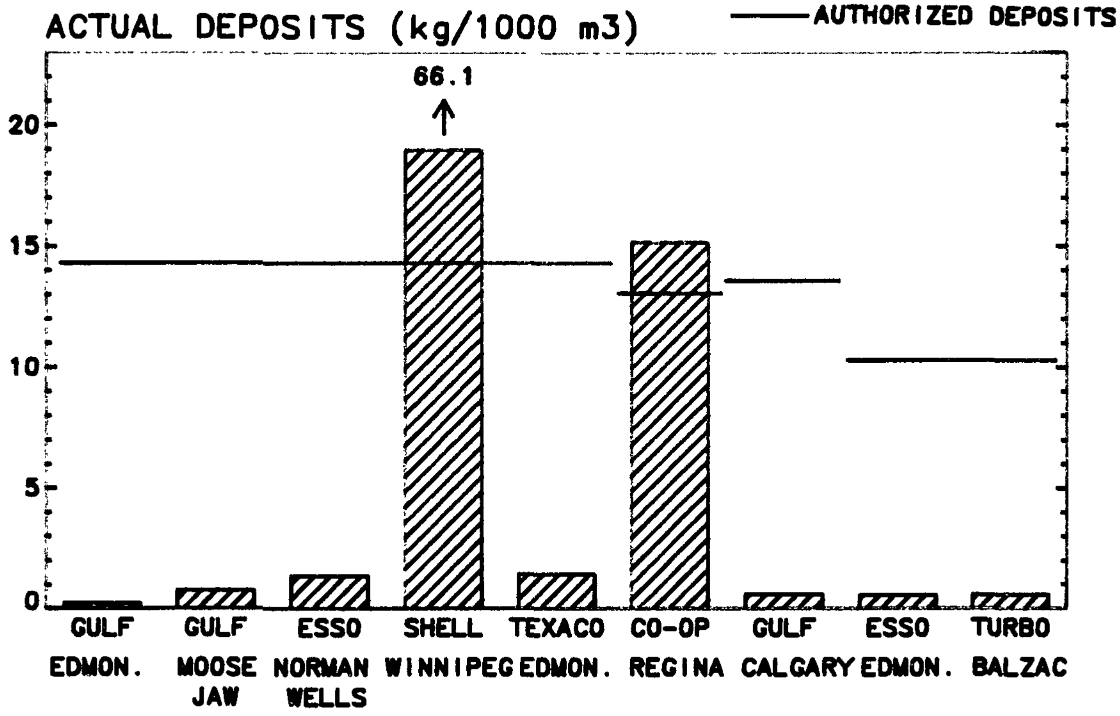


FIGURE 48 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY
(Western & Northern Region - 1983)

Gulf-Moose Jaw had the lowest suspended solids discharges. The Co-op refinery exceeded the phenols and the sulphide limits. In addition, Turbo and Gulf--Moose Jaw were also above the sulphide limits. For ammonia nitrogen, the Co-op refinery and Shell--Winnipeg (which was more than 370% above the limit) exceeded the annual authorized deposits.

The three refineries that were subject to the regulations had some violations. Turbo had problems with sulphide in 1983; the refinery exceeded the monthly limit 50% of the time. Turbo had just started operating in late 1982 and these violations can be attributed to difficulties in bringing the process units on stream. This resulted in an annual average that exceeded the authorized deposit for sulphide. The refinery was in compliance for the other parameters; however, no toxicity tests and only 60% of the required tests were reported. In 1984, Turbo's performance improved greatly with only one violation of the monthly amount for sulphide recorded. All the annual deposits were reduced and below the limits. The Esso refinery in Edmonton exceeded the monthly amount for oil and grease once, and occasionally (0.3% of the time) exceeded the daily limits for oil and grease, and total suspended solids. Only 1% of the tests required were not reported (mainly the toxicity test). The 1984 performance was very good with only one violation of the maximum daily amount of suspended solids possibly due to stormwater discharge for that day. The annual deposits for the two years were very small compared to the authorized levels. Shell--Scotford started operating late in 1984 and discharged effluent only in December. The refinery was in compliance with the monthly amounts for oil and grease, total suspended solids and with the pH limits. The company performed one test per week for only these parameters as per provincial requirements. However, only monthly averages were reported making the assessment of daily limits impossible.

Of all the required tests in the region, 35% were not reported in 1983. All the parameters were equally unreported except toxicity, where 80% of the tests were not reported. The overall production in 1983 was reduced by 11% from the 1980 level. The production increased by 7% the following year. The performance of each refinery in this region is presented in Table 29 giving 1983 and 1984 values for each parameter.

Gulf—Edmonton, Alta. The Gulf refinery in Edmonton has a primary treatment system and discharges its effluent into the North Saskatchewan River. Some wastes such as oily water from process areas are treated and deep-well injected. Gulf was considered an existing refinery subject to the guidelines in 1983 and 1984.

Gulf had a very good performance in 1983. The refinery was in compliance for all parameters except pH where a single deposit was outside the limit (this represents

TABLE 29 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Western & Northern Region - 1983, 1984)

		% of time not in compliance																
		Oil and Grease			Total Suspended Solids			Phenols			Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery		M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	N	N
Gulf	1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
(Edmonton)	1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulf	1983	0	*	*	0	*	*	0	*	*	40	*	*	0	*	*	0	NR
(Moose Jaw)	1984	0	*	*	0	*	*	0	*	*	0	*	*	0	*	*	0	0
Esso Petroleum	1983	75	39	15	100	67	48	0	0	0	12	0	0	0	0	0	0	0
(Norman Wells)	1984	50	-	-	92	-	-	0	0	0	0	0	0	8	0	-	0	0
Shell (Winnipeg)	1983	12	NR	NR	0	NR	NR	25	NR	NR	0	NR	NR	100	NR	NR	0	NR
Texaco	1983	0	0	0	0	0.8	0.8	0	0	0	0	0	0	0	0	0	0.3	0
(Edmonton)	1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co-op	1983	0	*	*	0	*	*	100	*	*	50	*	*	75	*	*	0	NR
(Regina)	1984	0	*	*	0	*	*	100	*	*	25	*	*	50	*	*	0	0
Gulf (Calgary)	1983	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Esso Petroleum	1983	8	1	1	0	0	0.6	0	0	0	0	0	0	0	0	0	0	20
(Edmonton)	1984	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0
Shell (Scotford)	1984	0	NR	NR	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	NR
Turbo	1983	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0.6	NR
(Balzac)	1984	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	NR

* insuffucient number of tests
NR - not reported
M - monthly amount; O - one-day amount; N - maximum daily amount

non-compliance 0.3% of the time). All the annual deposits were significantly below the limits. The refinery did not report 43% of the tests requested; for most of the parameters, more than 60% of the tests were missing.

In 1984, the refinery's performance was excellent with 100% in compliance for all parameters. The annual deposits were higher than those of 1983 but were still very low compared to the limits. The number of tests reported decreased in 1984; the percentage of tests not reported was 47%.

Gulf--Moose Jaw, Sask. This refinery has a primary treatment system and the effluent is further treated at the municipal treatment plant. However, Gulf did not receive an exemption from the guidelines. Part of Gulf's treated stormwater is discharged to Moose Jaw Creek. The refinery has an existing status and is subject to the guidelines.

Gulf was in compliance in 1983 for all parameters except for two monthly sulphide deposits. These two deposits were more than 200% above the limit, and one was more than 400% above the limit. However, the off-site effluent treatment would normally reduce the sulphide level. This evaluation is not a good indication of Gulf's performance because only one test per month was performed for each parameter rather than the requested three tests per week for the five parameters and one test per day for pH. The low number of tests made it impossible to assess compliance with the daily limits. In addition, Gulf did not perform any toxicity tests. In 1983, the annual deposits were all below the limits except for sulphide.

Although the 1984 assessment indicates complete compliance, the refinery performed the same number of tests as in 1983, which makes the assessment incomplete. All the annual deposits were below the limits.

Esso Petroleum--Norman Wells, NWT. The Esso refinery in Norman Wells has an API separator as a primary treatment system and the effluent is discharged into the Mackenzie River. The refinery is subject to the guidelines and has existing status.

The main problem in 1983 lay with oil and grease and total suspended solids. For these two parameters, the monthly amounts were exceeded 75% of the time and 100% of the time, respectively; the daily limits were also exceeded. The one-day amount of oil and grease was exceeded 39% of the time and suspended solids 67%; the maximum daily amount of oil and grease was exceeded 15% of the time and suspended solids 48% of the time. In addition, the monthly amount of sulphide was exceeded 12% of the time. The refinery was in compliance for all other parameters.

The 1983 annual average deposits of oil and grease and total suspended solids were both higher than the authorized levels. This has been an ongoing problem at Esso. An 18-week survey carried out by the company in 1984 indicated that the high solids concentration in the Mackenzie River, which supplies water to the refinery, caused the high total suspended solids readings. Once-through cooling water is sent with the liquid effluent to the API separator in this refinery, and therefore solids measured in the effluent contain solids from the cooling water.

The overall performance in 1983 was: 63% of the time in compliance with the monthly amounts, 79% with the one-day amounts, and 89% with the maximum daily amounts. The majority of the deposits (67%) that exceeded the monthly amounts were more than 200% above the limit and the rest were between 100 and 200% above the limit.

Esso has been monitoring effluent once per week for each chemical parameter and twice per year for toxicity according to the Northwest Territories Water Board requirements pursuant to the Northern Inland Waters Act. Although the refinery has not been reporting in accordance with the federal guidelines, based on the size and nature of the operation and lack of on-site analytical capabilities, Environment Canada is satisfied with the sampling frequency requested by the Board. Based on the Water Board requirements, Esso reported 69% of the tests in 1983 and increased to more than 99% in 1984.

In 1984, the refinery's performance improved slightly, but the number of deposits above the limits was still high. The monthly amounts were exceeded 50% of the time for oil and grease, 92% of the time for total suspended solids, and 8% of the time for ammonia nitrogen. Fewer deposits exceeded the daily limits. The majority of the excessive deposits of oil and grease occurred in the first four months of 1984. After these incidences, Esso upgraded the API separator and installed a pre-separator. These measures reduced the oil and grease levels. The high suspended solids levels were proven to be caused by the high levels in the Mackenzie River. If net loadings of suspended solids in the effluent had been calculated, the company might have met the limit. The annual deposits were reduced for all parameters except ammonia nitrogen. The deposits of oil and grease, and the total suspended solids, however, were still above the limits.

Shell--Bowden, Alta. The Shell refinery in Bowden had an existing status and was subject to the guidelines. Shell had a primary treatment system (API separator) and discharged its effluent on an intermittent basis to a drainage ditch which leads to the Red Deer River. In 1983 and 1984, the refinery did not discharge any effluent into the river.

Shell--Winnipeg, Man. The Shell refinery in Winnipeg (St. Boniface) had an intermediate treatment system (aerated pond) and discharged its effluent to the Winnipeg sewer for biological treatment. This off-site treatment was considered to give equivalent treatment for all parameters except possibly ammonia nitrogen. The refinery was permanently shut down in October 1983.

Shell was an existing refinery and therefore subject to the guidelines. During its operation in 1983, the refinery effluent, prior to off-site secondary treatment, was in compliance for total suspended solids, sulphide and pH. High monthly deposits were recorded for oil and grease, phenols and ammonia nitrogen (12% of the time, 25%, and 100%, respectively). The oil and grease, and the phenols deposits were considered to be within the guidelines because the effluent undergoes further treatment. However, as stated earlier, the high deposits of ammonia nitrogen could still remain high after the off-site treatment. No toxicity test was performed and 53% of all the tests were not reported. The annual deposits were all below the authorized limit.

Texaco--Edmonton, Alta. Texaco, Edmonton treated its wastewater with an intermediate system of dissolved air flotation, and discharged the effluent into the North Saskatchewan River. The sour waters were treated and deep-well injected. The refinery was permanently shut down in May 1984 and had an existing status under the guidelines in 1983 and 1984.

Texaco had a very good performance in 1983; only few deposits exceeded the daily limits of suspended solids and pH level. The refinery was in compliance with the monthly amounts 100% of the time and 99.8% with the daily limits. In addition, the annual deposits were very low compared to the limits. Thirteen percent of the requested tests were not reported.

During its operation in 1984, the refinery was in full compliance with all the limits. The annual deposits were below the 1983 levels and under the limits. Most of the tests requested were provided.

Co-op--Regina, Sask. This Consumers Co-op refinery has a primary treatment system and discharges its effluent to the Regina Municipal sewer for further treatment. The Co-op was in compliance "at the refinery fence" in 1981 and was therefore given a two-year exemption in 1982 from the normal reporting requirements under the federal refinery effluent guidelines. The exemption allowed Co-op to report only tri-monthly averages on its effluent, and toxicity tests were not required. The refinery has an expanded status and is subject to the guidelines.

Since 1982, however, effluent quality has deteriorated considerably. Although Co-op was in compliance in 1983 for oil and grease, total suspended solids, and pH levels, monthly deposits above the authorized limits for phenols, ammonia nitrogen and sulphide occurred. These monthly deposits were actually tri-monthly problems. The refinery exceeded the limits at the refinery fence 100% of the time for phenols, 50% of the time for sulphide and 75% of the time for ammonia nitrogen. Measures have been taken to reduce sulphide discharges. As for phenols and ammonia nitrogen, the company has not yet provided any evidence that the off-site treatment achieves an adequate reduction. The annual deposits of phenols, sulphide (14 times higher than the limit) and ammonia at the refinery fence were above the authorized levels.

The refinery's performance improved slightly in 1984 but the same parameters were of concern: 100% of the time not in compliance for phenols, 25% for sulphide and 50% for ammonia nitrogen. The annual deposits were similar to the 1983 levels and were above the limits for the same three parameters. In view of the unsatisfactory effluent quality of 1983 and 1984, serious reservations apply to granting Co-op another exemption.

Gulf--Calgary, Alta. The Gulf refinery in Calgary had an intermediate treatment system (dissolved air flotation) and discharged its effluent into the Bow River. Gulf operated for 10 months during 1983 and was permanently shut down in December 1983.

In 1983, the refinery had an expanded status and was essentially in compliance 100% of the time except for one deposit of oil and grease that exceeded the maximum daily amount. All the actual annual deposits were below the authorized limits. Only 68% of the requested tests were reported.

Husky--Lloydminster, Alta. Husky decommissioned its old refinery in March 1983 and a new refinery was built adjacent to the old one and brought on line in May 1983. Both refineries used solely deep-well injection for the disposal of their treated effluent. Since no wastewaters were discharged to water frequented by fish, the refinery effluent is not subject to the federal regulations.

Esso Petroleum--Edmonton, Alta. Esso Petroleum in Edmonton is a new refinery and is subject to the regulations. The refinery has a secondary treatment system consisting of an aerated lagoon and the effluent is discharged into the North Saskatchewan River. In addition, Esso uses deep-well injection for sour water.

Esso was in compliance in 1983 for most of the parameters. The refinery had one violation of the monthly amount for oil and grease and two violations of the daily limits. In addition, one deposit of suspended solids was above the maximum daily amount. All the annual deposits were below the authorized limits. The refinery reported 99% of all the required tests, but reported only 42% of the required toxicity tests.

In 1983, Esso was in compliance 98% of the time with the monthly amounts and 99.7% of the time with the daily limits. The monthly violation was less than 24% above the limit.

The 1984 performance was almost 100% in compliance with all the limits. Only a single violation of the maximum daily amount of total suspended solids occurred. This high level of total suspended solids was possibly due to stormwater discharge for that day. The refinery reported more than 99% of the tests required, although an insufficient number of toxicity tests were performed (only 25% reported). Most of the annual average deposits were lower than the 1983 levels and all of them were still below the limits.

Turbo Resources--Balzac, Alta. Turbo is a new refinery that was commissioned in September, 1982. The refinery has an intermediate treatment system which includes an air flotation unit and a hay filter. The effluent is discharged into McDonald Lake. Process condensates and wastewaters are deep-well injected.

Turbo was in compliance in 1983 for most of the parameters except sulphide. The refinery exceeded the sulphide monthly amount 50% of the time which resulted in an annual average that was above the limit. Turbo had just started operation in late 1982 and the sulphide violations may have been due to difficulties in bringing the process units on stream. The annual deposits of the other parameters were below the limits. Of the total number of tests required, more than 40% were not reported and no toxicity tests were performed.

Performance improved significantly in 1984 and Turbo was in compliance with the monthly amounts 98% of the time compared to 89% in 1983. The refinery was in compliance for most of the parameters except sulphide where one violation of the monthly amount occurred. In addition, for stormwater, four violations of the total suspended solids limit occurred and one for phenols; toxicity tests were not performed. Although most of the annual average deposits had increased since 1983, they were still below the authorized level.

Shell--Scotford, Alta. The Scotford refinery started operation in September 1984 and was designed to use very little water. In December 1984, the refinery commenced discharging effluent (consisting of zeolite backwash, boiler blowdown and sanitary wastewater) and stormwater (on a periodic basis).

The company was in compliance with the monthly amounts for oil and grease, total suspended solids and with the pH limits. One test per week was performed for only these parameters, as required by the province. However, only monthly averages were reported, making the assessment of daily limits impossible.

4.4.6 Pacific & Yukon Region Assessment. In 1983, seven refineries were operating in British Columbia subject to the guidelines. Only one of them (Chevron) had an expanded status; the others had an existing status. Five of the seven refineries discharged their effluents to off-site treatment systems. The extent to which the municipal sewage treatment plants which receive the refineries' effluent provide adequate treatment has yet to be determined. None of these refineries have applied for exemptions from the controls or from the normal monitoring requirements of the guidelines. The Gulf--Kamloops refinery was permanently shut down on May 30, 1983, leaving six operating refineries in the region. The facility now receives gasoline from Alberta and is utilized as a distribution terminal. The Petro-Canada refinery at Taylor also treats the effluent generated by an associated natural gas plant. The performance of each refinery in 1983 is summarized in Appendix B.

In 1983, the region was in compliance with the monthly amounts 95% of the time. Four refineries were in compliance with the monthly amounts 100% of the time. The other three, Gulf--Kamloops, Petro-Canada and Chevron were in compliance 92% of the time, 88% of the time, and 83% of the time, respectively. Gulf's and Chevron's effluents receive further treatment offsite. As shown in Figure 2, 46% of the deposits that exceeded the monthly amounts and the stormwater limits were less than 50% above the limit and 86% were less than 200% above the limit. In addition, the region was in compliance 99% of the time with the one-day amounts, 95% with maximum daily amounts and 91% with the stormwater limits. The parameters that were exceeded most were phenols and toxicity. Discharges of phenols exceeded the monthly amount 9% of the time and the toxicity tests failed 19% of the time.

The overall regional performance in 1983 was superior to that of 1980. The actual number of deposits that exceeded the limits decreased for all parameters except toxicity which was above the limit 9% of the time in 1980 and increased to 19% in 1983. Compliance with the monthly amounts (of all the parameters) increased from 81% in 1980 to 95% in 1983. Stormwater deposits were in compliance with the limits 78% of the time in 1980 and 92% of the time in 1983. The performance continued to improve in 1984 when the region was in compliance with the monthly amounts 96% of the time. There were also fewer deposits exceeding the daily limits, but stormwater deposits in excess of the limits increased slightly (89% of the time).

The annual average of regional deposits from 1972 to 1984 is illustrated in Figures 49 to 53. As shown, there was a reduction in the 1983 discharges of all five parameters compared to the 1980 levels. Reductions of deposits ranged from a maximum of 82% for sulphide to 18% for total suspended solids. The 1984 annual deposits increased slightly compared to the 1983 levels; however, the discharge levels for 1983 and 1984 were all below the authorized limits.

A comparison of the 1983 yearly deposits for the refineries in the region is presented in Figures 54 to 58. Apart from phenols discharge at Chevron, all the annual deposits of the refineries were below the authorized levels. Oil and grease deposits were generally very low; Esso had the lowest level and Chevron the highest. Most of the total suspended solids discharge levels were the same for each refinery except Husky which had a very low level and Chevron which had the highest level in the region. For phenols, Chevron was above the limit and Gulf--Kamloops had the second highest level, although the discharges were below the limits. Husky and Shell had the lowest phenols deposits. The sulphide discharge levels of four refineries (Esso, Husky, Shell and Chevron) were close to zero and two other refineries (Gulf--Kamloops and Petro-Canada) discharged 70% of the authorized limit. The highest ammonia nitrogen level was discharged by Petro-Canada and the two Gulf refineries (Port Moody and Kamloops) had the lowest levels.

As a result of different provincial reporting requirements, not one refinery submitted data as often as specified in the guidelines. On average, the refineries reported only 25% of the tests requested in 1983 (the range was from 22% to 27%). In assessing the refineries' performance, therefore, the percentage of time that each refinery was in compliance is a better indicator than the actual number of deposits that were above the limits. The number of tests reported in 1984 was in the same range. The annual production was reduced in 1983 by 8% compared to 1980, and a further 11% reduction occurred in 1984. These reductions were partly caused by the closure of Gulf in Kamloops. The performance of each refinery in this region is presented in Table 30 giving 1983 and 1984 values for each parameter.

Esso Petroleum--Ioco. This Esso Petroleum refinery treats its effluent with an activated sludge system and discharges it into Burrard Inlet. Some stormwater is segregated from process water and treated separately. The refinery is subject to the guidelines.

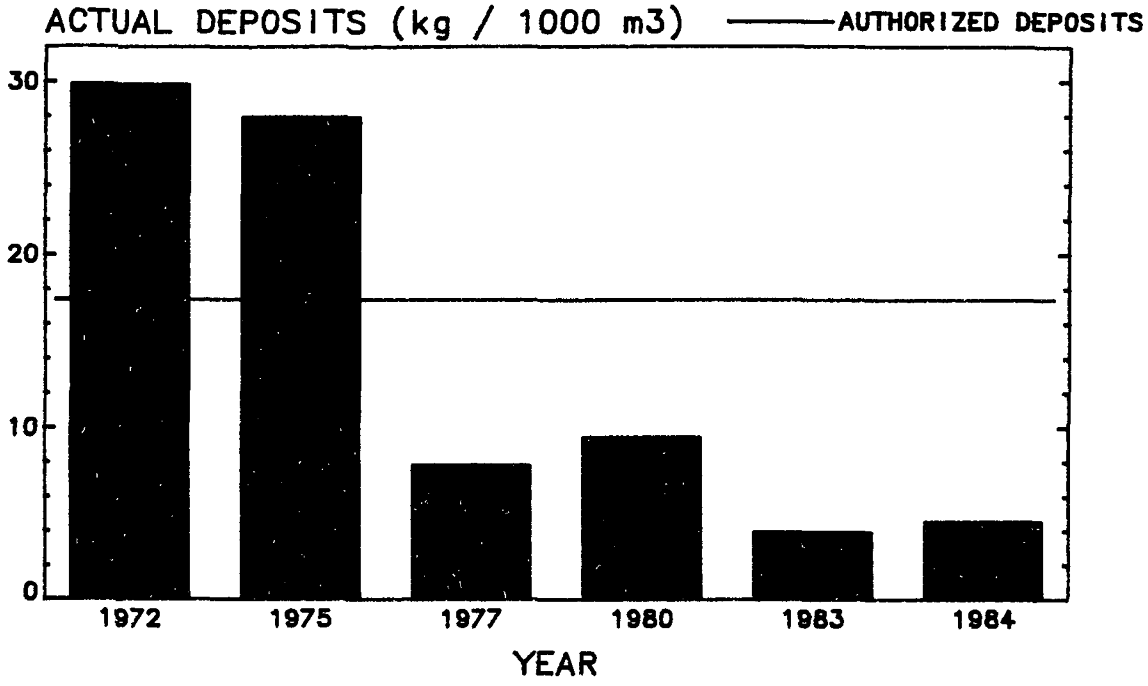


FIGURE 49 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Pacific & Yukon Region - 1972 to 1984)

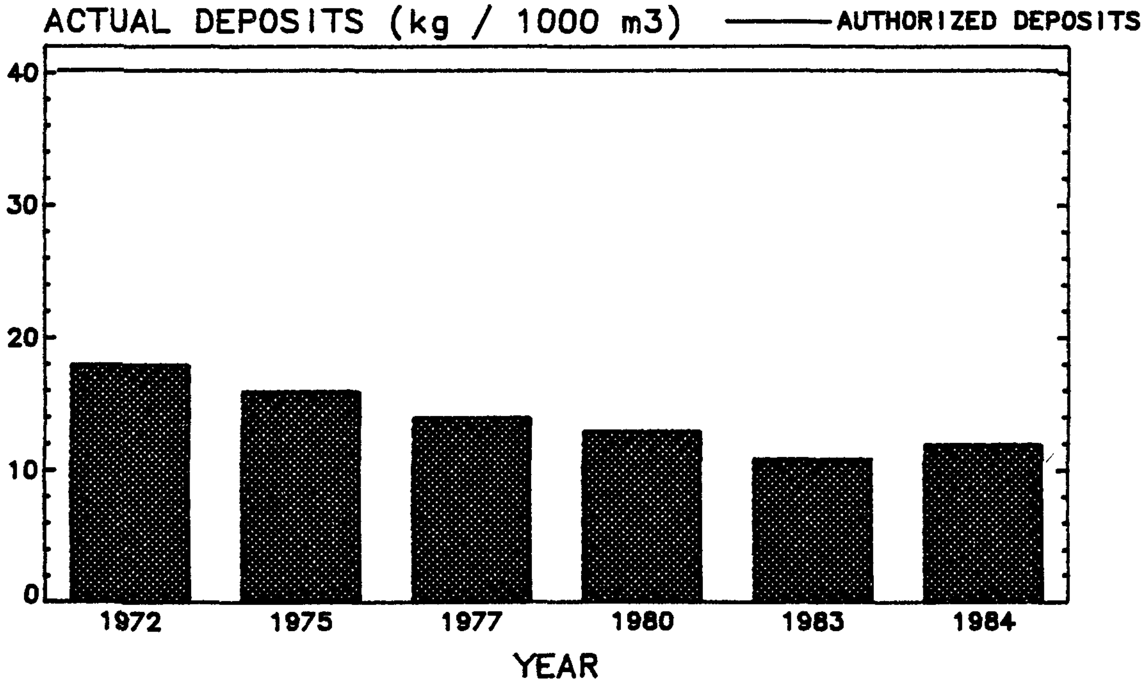


FIGURE 50 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Pacific & Yukon Region - 1972 to 1984)

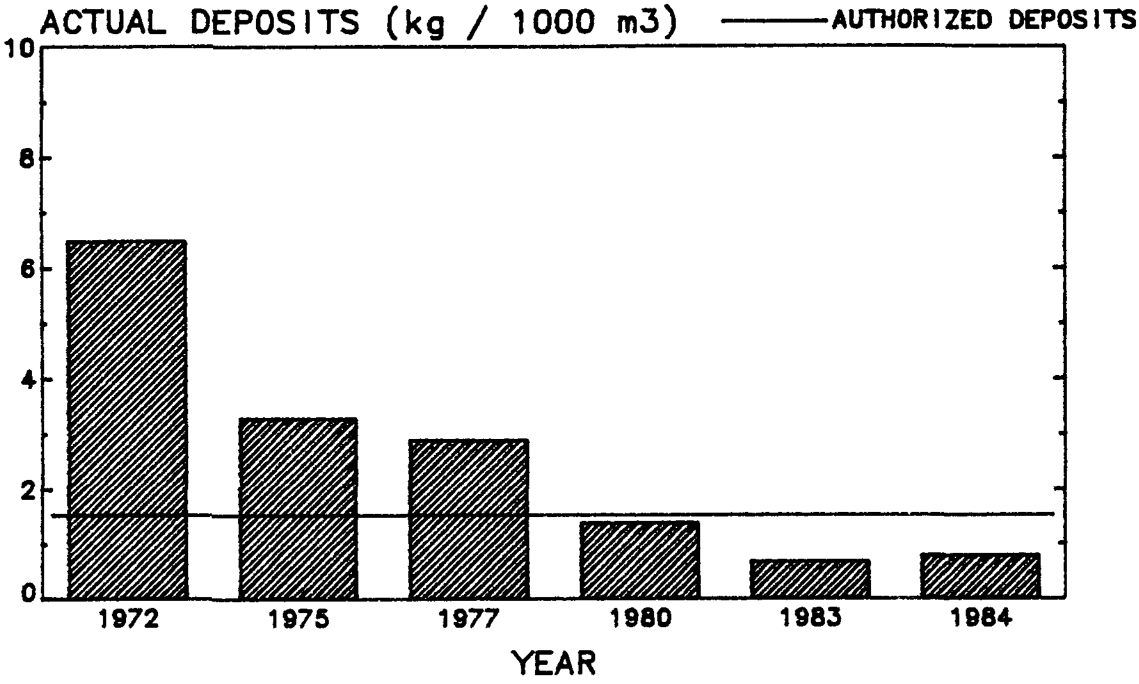


FIGURE 51 AVERAGE ANNUAL DISCHARGES OF PHENOLS
(Pacific & Yukon Region - 1972 to 1984)

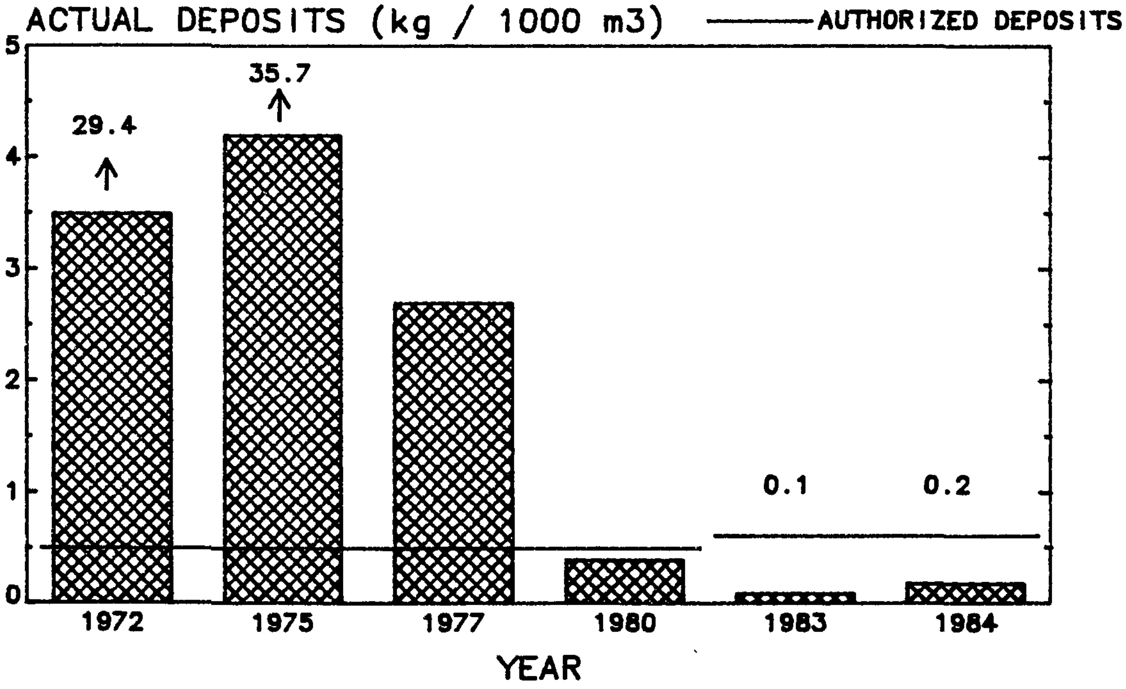


FIGURE 52 AVERAGE ANNUAL DISCHARGES OF SULPHIDE
(Pacific & Yukon Region - 1972 to 1984)

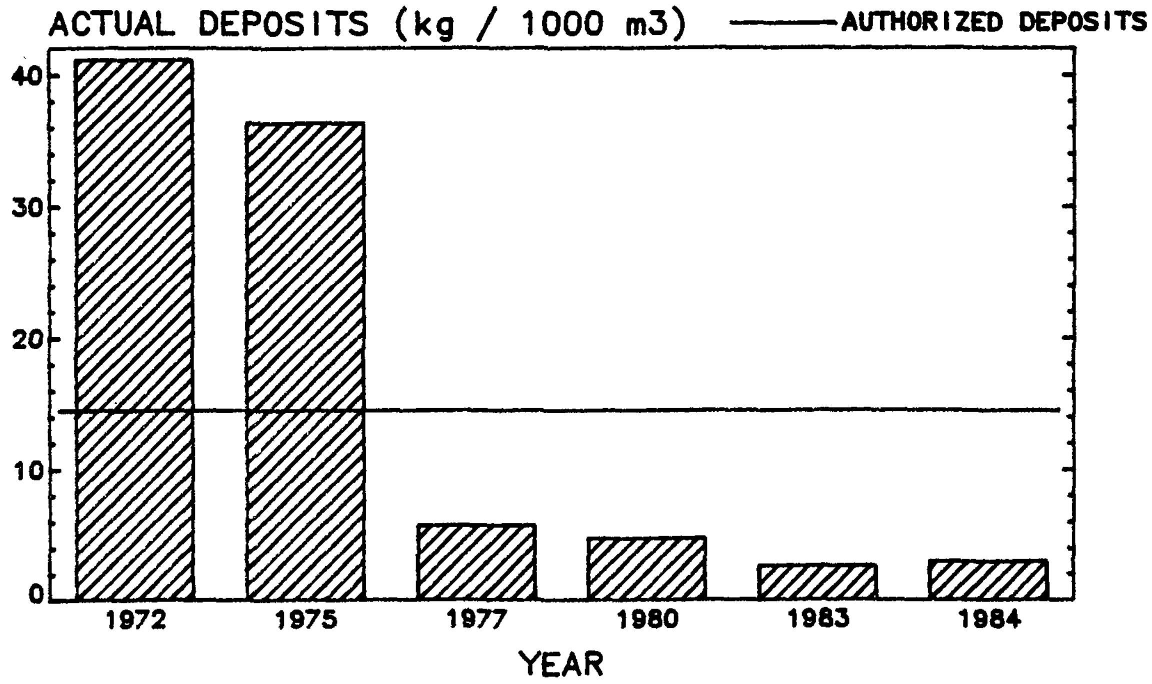


FIGURE 53 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Pacific & Yukon Region - 1972 to 1984)

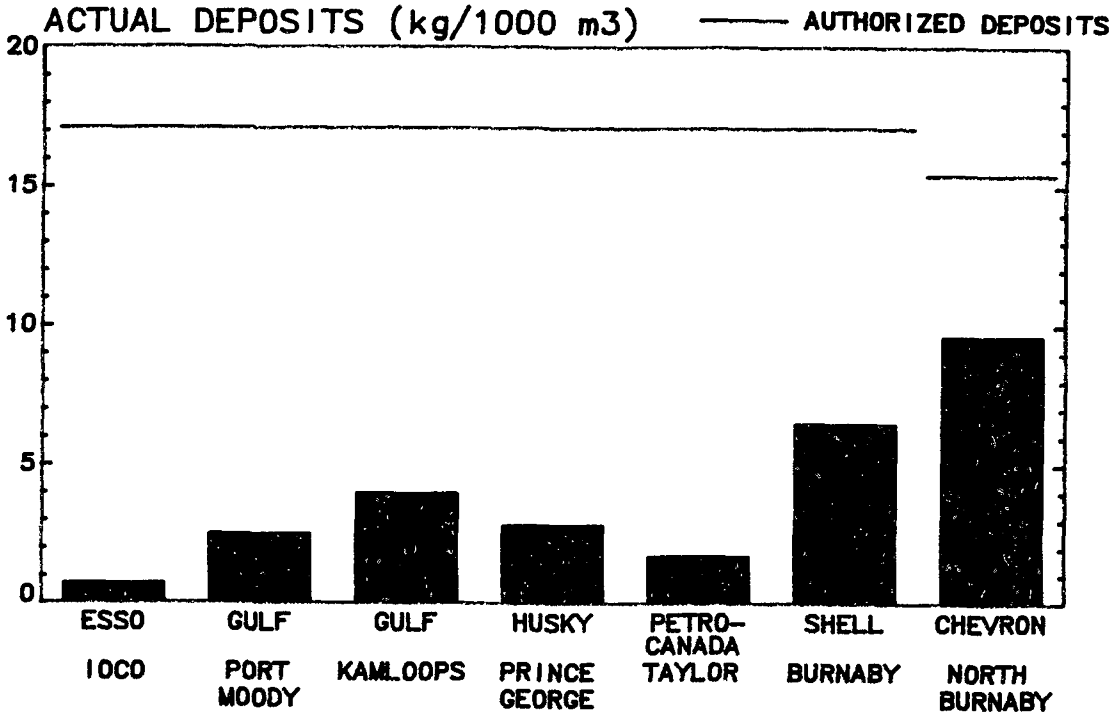


FIGURE 54 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1983)

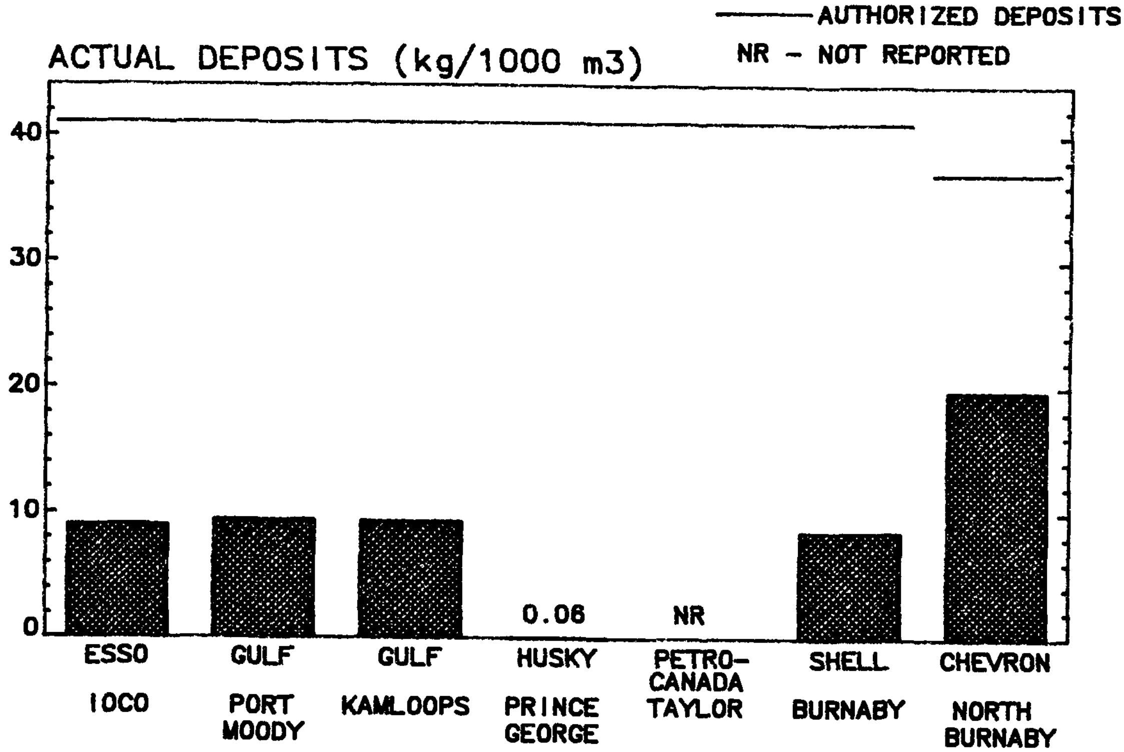


FIGURE 55 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1983)

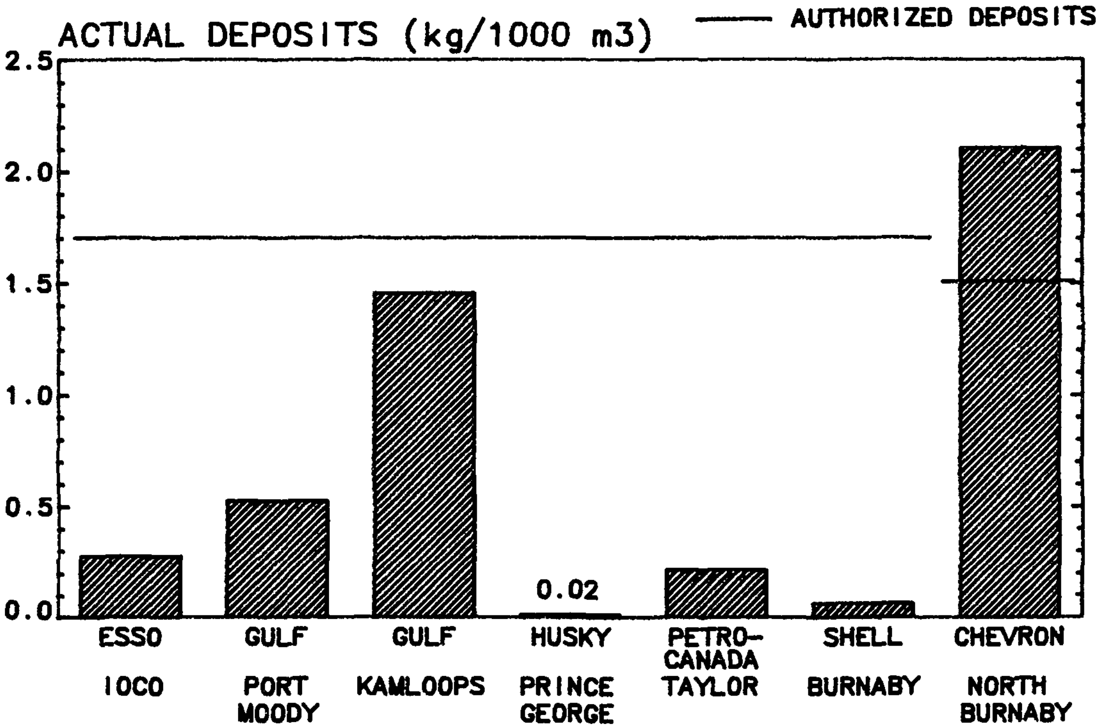


FIGURE 56 PHENOLS DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1983)

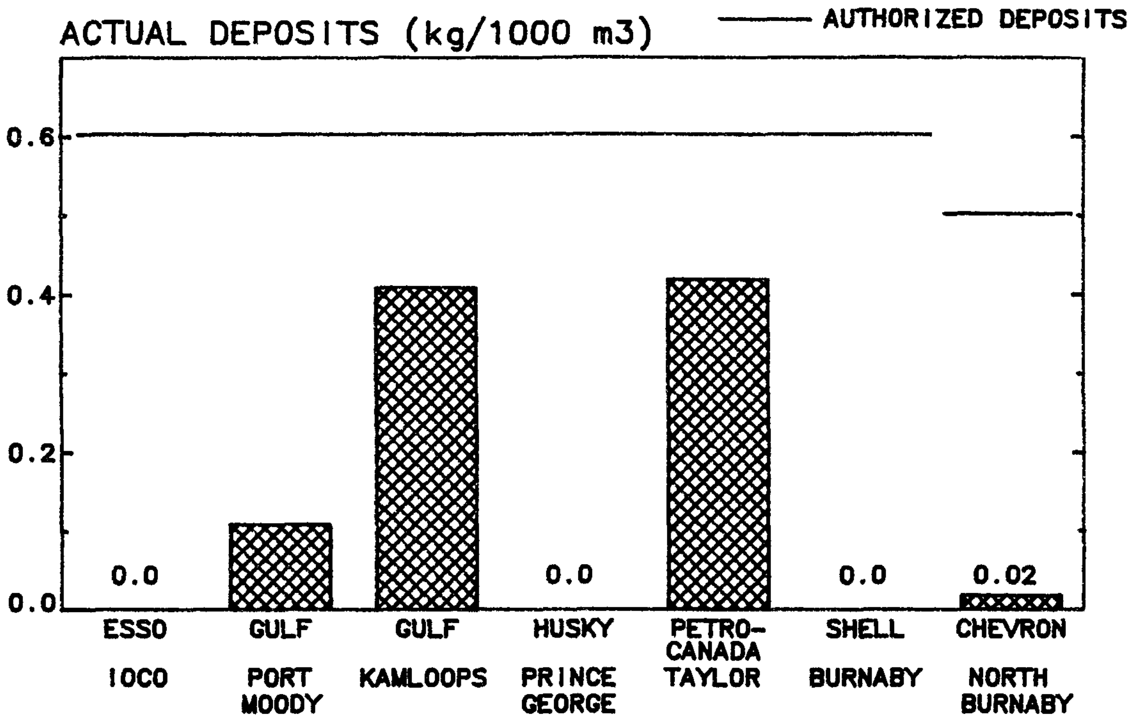


FIGURE 57 SULPHIDE DISCHARGE LEVELS BY REFINERY
(Pacific & Yukon Region - 1983)

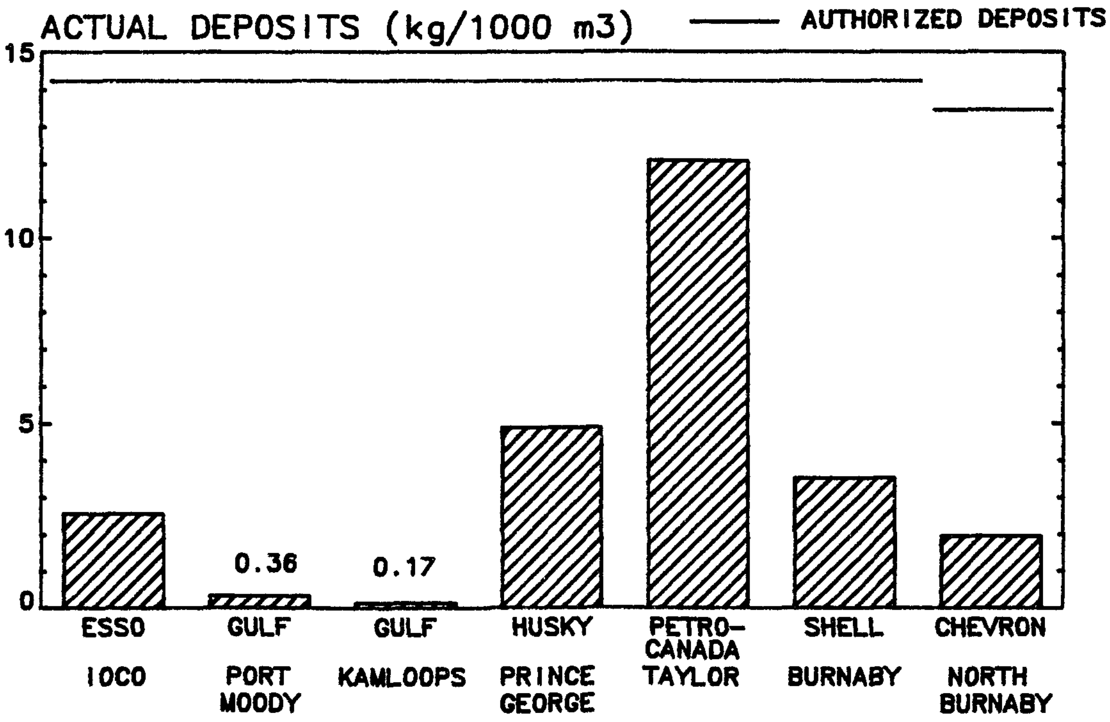


FIGURE 58 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY
(Pacific & Yukon Region - 1983)

TABLE 30 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Pacific & Yukon Region - 1983, 1984)

		% of time not in compliance																			
		Oil and Grease				Total Suspended Solids				Phenols				Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery		M	O	N	S	M	O	N	S	M	O	N	S	M	O	N	M	O	N	N	N
Esso Petroleum (Ioco)	1983	0	0	0	45	0	0	0	91	0	0	0	0	0	0	0	0	0	0	4	100
	1984	0	0	0	25	0	0	0	100	17	2	2	0	17	0	2	0	0	0	4	0
Gulf (Port Moody)	1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	8	0	0	0	17	0	0	0	0	0	0	0
Gulf (Kamloops)	1983	0	0	0	-	0	0	0	-	14	10	14	-	14	5	0	0	0	0	7	NR
Husky (Prince George)	1983	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	0	0	0	2	75
	1984	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	0	0	0	2	0
Petro-Canada (Taylor)	1983	0	0	0	0	0	0	0	8	8	0	2	0	17	0	0	33	8	10	0	0
	1984	0	0	0	0	-	-	-	17	0	0	0	0	0	0	0	8	0	0	0	0
Shell (Burnaby)	1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
	1984	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	8
Chevron (North Burnaby)	1983	25	0	2	0	17	0	6	0	42	12	23	0	0	0	0	0	0	0	8	0
	1984	0	0	0	8	0	0	0	0	50	0	6	0	0	0	0	0	0	0	2	0

M - monthly amount; O - one-day amount; N - maximum daily amount; S - stormwater limit
NR - not reported

In 1983, Esso's process water was in compliance for all the parameters except toxicity (two test failures out of two tests reported) and pH. Esso's major problem was associated with stormwater. Oil and grease, and total suspended solids deposits in stormwater exceeded the limits 45% of the time and 91% of the time, respectively. Twenty percent of these high deposits were more than 200% above the limit, and 40% were between 50 and 100% above the limits. Excessive stormwater discharges have been an on-going problem.

In a four-day Environment Canada survey conducted in March 1983, the refinery effluent was 100% in compliance with all the limits.

The overall performance in 1983 was: 100% in compliance with the monthly and the one-day amounts; 99% of the time in compliance with the maximum daily amounts; and only 58% of the time in compliance with the stormwater limits. The annual averages for deposits were very low compared to the limits for process water. The annual deposits in stormwater, however, were above the limits for oil and grease, and total suspended solids. The refinery reported only 27% of the tests requested.

In 1984, the refinery effluent quality decreased. For process wastewater, the monthly amounts of phenols and sulphide were exceeded 17% of the time. A few deposits exceeded the authorized pH level. Stormwater continued to exceed the oil and grease and total suspended solid limits (100% of the time). While Esso has upgraded the treatment system, additional work is still required. The performance in 1984 was: 93% of the time in compliance with monthly amounts; almost 100% for the one-day amounts; 99% for the maximum daily amounts; and 58% for the stormwater limits. The annual deposits in process water were generally lower than the 1983 levels and are still below the limits. For stormwater, the oil and grease annual average was just at the limit and the suspended solids were still above the limit. The changes made in 1984 to the wastewater treatment system (which included the replacement of an aerator in the biological system, and the recovery of sludge from the stormwater retention lagoon) began to show effects in 1986, when the effluent quality improved.

Gulf—Port Moody. The Gulf refinery in Port Moody segregates its stormwater from process wastewater and treats each separately in with a primary treatment system. The process effluent is forwarded to the Greater Vancouver Regional District (GVRD) sewer, while stormwater is discharged into Burrard Inlet. The refinery is subject to the guidelines.

Gulf had an excellent performance in 1983 since both process and stormwaters were in full compliance with all the limits at the refinery fence. Three Environment Canada audits (one day each), performed in January and February 1983, reported Gulf to be in full compliance with all the limits. In addition, all the annual deposits were below the limits. Only 27% of the requested tests were reported.

The 1984 performance was not as good. Some deposits exceeded the monthly amounts for phenols and sulphide in process water. All other deposits were in compliance. The overall performance was therefore reduced to 95% of the time in compliance with the monthly amounts, but still 100% of the time in compliance with the daily and the stormwater limits. Most of the annual deposits in process water increased from the 1983 level, but were still below the limits. The annual deposits in stormwater decreased and were again below the limits.

Gulf--Kamloops. The Gulf refinery in Kamloops was permanently shut down on May 30, 1983, but effluent monitoring continued until the end of July. The tank farm is now being used as a distribution terminal. The refinery had a primary treatment system which treated the combined process and stormwaters. The effluent was sent to the municipal treatment plant for the City of Kamloops. Gulf was subject to the guidelines.

During the five months it was operating, the refinery was in compliance for oil and grease, total suspended solids, and ammonia nitrogen. Deposits exceeding the monthly and daily limits were recorded for phenols and sulphide. The monthly amounts of these two parameters were exceeded 14% of the time. The phenols deposit was more than 200% above the limit and the sulphide deposit 100% above the monthly limit. The pH level was also exceeded 7% of the time and no toxicity tests were reported. The effluent received further treatment off-site, which may have improved the final quality.

Gulf was in compliance 94% of the time with the monthly amounts and 97% of the time with all the daily limits. Twenty-six percent of the tests requested were reported. The annual deposits were all below the authorized levels.

Husky--Prince George. Husky treats its effluent (stormwater is combined) with an intermediate treatment system (aerated pond) before sending it to a local pulp mill for biological treatment. The effluent "at the refinery fence" is subject to the guidelines.

In 1983, Husky was in compliance for all parameters except toxicity and pH. The effluent failed to pass the toxicity test 75% of the time. To solve the perennial toxicity problem, Husky intended to upgrade the sour water stripper and clean the aeration pond in early 1984. In 1983, the refinery was in compliance 100% of the time with the monthly amounts and the one-day amounts, and 96% of the time with the maximum daily amounts. The annual deposits were all below the limits. Husky reported only 24% of the tests requested.

The 1984 performance improved considerably following installation of a surge equalization system and a sour water stripping system, and the problems of toxicity were resolved. The refinery was essentially 100% in compliance except for deposits that exceeded the authorized pH levels (2% of the time). Most of the annual deposits were lower than the 1983 levels and were again below the authorized levels.

Petro-Canada--Taylor. This Petro-Canada refinery is associated with a sour natural gas plant. The combined effluent is treated in an activated sludge system and discharged into the Peace River. Stormwater from the two facilities is segregated from process effluent and treated in a primary system before being discharged into the same river. The combined (refinery and natural gas plant) effluent was assessed against the guidelines limits.

During 1983, Petro-Canada's process water was in full compliance for oil and grease, total suspended solids, pH, and toxicity. The monthly amounts of ammonia nitrogen, sulphide and phenols were exceeded. A few deposits of ammonia and phenols were above the daily limits. In addition, total suspended solids exceeded the stormwater limit. The high deposits of sulphide occurred during the first quarter of 1983 and were caused in part by analytical errors that were corrected in May 1983. Petro-Canada believed that the deposits of the gas plant made a significant contribution to the total effluent deposits (especially ammonia nitrogen) and applied to the provincial authorities for a permit amendment to account for this contribution. Furthermore, a new NGL (natural gas liquids) plant at the complex site was due to come on-line in the fall of 1985. This will further tax the existing wastewater treatment facilities.

In 1983, the refinery was in compliance with the monthly amounts 88% of the time, and more than 97% of the time with the daily and the stormwater limits. Most of the deposits (63%) that exceeded the monthly amounts were less than 25% above the limit. Due to high levels of suspended solids in the Peace River, most of the calculated net deposits for this parameter were negative. All the annual deposits were below the limits, although sulphide and ammonia nitrogen were close to the limit. The refinery reported only 27% of the requested tests.

Petro-Canada had a better performance in 1984. For process wastewater, only ammonia nitrogen exceeded the monthly amount limit. In addition, the total suspended solids deposits exceeded the stormwater limit. The overall performance was: 98% of the time in compliance with the monthly amounts, full compliance with the daily limits, and 94% of the time in compliance with the stormwater limits. All the annual deposits were reduced, particularly the ammonia deposits which had been closest to the limit in 1983. The deposits were still below the limits.

Shell—Burnaby. This Shell refinery has an intermediate treatment system (air flotation unit) and discharges its effluent to the GVRD sewer. Stormwater is treated separately at the refinery and discharged into Burrard Inlet. The refinery is subject to the guidelines.

In 1983, Shell was essentially in full compliance apart from one toxicity test failure (8% of the time). The company has installed facilities for the addition of a polyelectrolyte on the discharge from the pH control tank primarily to improve the operating efficiency of the air flotation unit. Stormwater deposits were also 100% in compliance. Overall, the refinery was in compliance with the monthly amounts, the one-day amounts and the stormwater limits 100% of the time, and 99% of the time in compliance with the maximum daily amounts. The company reported just 25% of the tests requested. All the annual deposits were below the authorized levels.

In 1984, the refinery's performance was similar although, in addition to one toxicity failure for process water, total suspended solids in stormwater exceeded the limit 8% of the time. Most of the annual deposits increased over the 1983 levels but stayed below the limits.

Chevron—North Burnaby. Chevron is the only refinery in the region that had an expanded status under the guidelines. The refinery uses two segregated wastewater treatment systems for process and storm waters. The process wastewater treatment system includes an air flotation unit (intermediate system) and the effluent is discharged into the GVRD sewer. Stormwater, undergoes a similar treatment but is discharged into Burrard Inlet.

In 1983, many of the refinery's deposits were above the limits. The parameters of concern were: phenols, oil and grease, total suspended solids and, to a lesser degree, pH. The stormwater deposits were always below the limits. High levels of phenol monthly deposits were partly caused by sour water stripper upsets and by problems with the gasoline caustic treating system. Chevron installed a new solid bed gasoline treatment system for catalytic cracked gasolines late in 1983 which helped to reduce phenols loadings by 23% in 1984. The monthly amounts of oil and grease, and total suspended solids were exceeded along with several deposits that were above the allowable maximum daily amounts. Heavy solids buildup in the de-oiling system was responsible for the high oil and grease values and possibly for part of the high suspended solids level. A cleanup of the de-oiling system reduced the oil and grease deposits to a level below the limit, but the suspended solids discharges were not reduced to the same extent. The pH level of the effluent was outside the acceptable range. Chevron has experienced chronic problems with wide pH fluctuations since 1979. A diethanolamine (DEA) system was installed to allow additional sulphur removal, resulting in an increase in the pH control.

In 1983, Chevron was in compliance with the monthly amounts 83% of the time, 98% of the time with the one-day amounts, 92% of the time with the maximum daily amounts, and 100% of the time with the stormwater limits. Chevron reported only 22% of the tests requested. The phenols annual deposit in process water was above the authorized level, but all other annual deposits (including those in stormwater) were below the limits.

In 1984, the overall performance improved. Chevron was in compliance with monthly amounts 90% of the time, 100% with the one-day amounts, and more than 97% with the maximum daily amounts and the stormwater limits. In process water, phenols and pH were the only two parameters that were exceeded. The monthly amounts for phenols were exceeded (50% of the time) because of leaks in the phenolic water collection system piping. The pH level was only exceeded 2% of the time. One deposit of oil and grease exceeded the stormwater limit. Most of the annual deposits were reduced slightly, although phenols deposits in process water were still above the limit. All the other annual deposits were below the limits.

5 SOLID WASTES AND SLUDGES

5.1 Regulatory Requirements

The provinces and municipalities have regulations and by-laws controlling the disposal of wastes to landfills. Some regulatory controls are also applied to these facilities and landspreading operations to prevent health hazards and protect groundwater. Provincial regulations specific to petroleum refineries have not been developed, although some provinces (e.g., British Columbia) have guidelines. Refineries in Quebec must comply with provincial regulations for solid waste and for hazardous waste (15, 16). Some provinces also incorporate solid waste management practices into clean water or landfarm permits. Federal legislation controlling the disposal of solid wastes has not been established.

5.2 Characterization and Quantities of Waste Generated

The reported average compositions (% weight) of oil, water, and solids in a number of the solid wastes are summarized in Table 31. Attempts to characterize chemical components of some refinery oily sludges have been made in a number of studies. The literature generally contains more information on concentrations of trace metals than organics because analytical methodologies for trace organics in sludges have just been developed and still need to be refined. In an analysis of sludges that can be applied to land for treatment, trace metals such as iron, chromium, lead, zinc, copper and vanadium appear to be present in higher concentrations (than in other refinery waste) in API separator bottoms, flotation froth, biological sludge, and pond bottoms. Based on the limited data on organic compounds in sludges, the following compounds can be present in the sludge: volatiles such as benzene, toluene, ethylbenzene; acid extractables such as phenols and alkyl-substituted phenols; and base-neutrals such as PAH (polynuclear aromatic hydrocarbons) and n-alkanes in the C_{10} to C_{30} range. The concentrations of these trace substances in sludges that are disposed of on land have been compiled in a literature survey (17).

A survey was conducted by PACE to identify the quantities of waste generated during various refining processes for the year 1978. Thirty-eight refineries provided annual estimates of generated waste and indicated disposal practices. A summary of the information compiled by PACE follows (18).

TABLE 31 AVERAGE CONTENTS OF OIL, WATER AND SOLIDS IN SOME REFINERY WASTES

	Average Composition or Range (% weight)		
Waste Type	Oil	Water	Solids
Desalting sludge	25.5	53	21.5
Spent cracking catalyst, thermal coke, coke fines, hydrocracking catalyst			100
Spent sulphuric acid* (90% H_2SO_4)		10	
Spent alumina			100
Acid oil	50 to 100	0 to 50	
Neutralization Pit Sludge	0.5	66.5	33
Caustic Phenols*	1 to 35	86 to 97	0 to 12
Caustic Sulphides*	0 to 5	77 to 100	5 to 23
Caustic (other)*	5 to 15	90 to 100	0 to 10
Spent acid*		99 to 100	0 to 1
DEA/MEA Sludge*		70 to 99	1 to 40
Spent clay and sand, off-specification sulphur, filters			100
Glycol waste from BTX operation* (90% glycol)		10	
Solvent from BTX operation	80	10	10
Lube and grease production waste	85 to 100	4 to 50	0 to 15
Asphalt spills and off-specification	60 to 100		0 to 40
Spent activated carbons	0 to 15	0 to 15	70 to 100
API sludge	7.5	62	30.5
Flotation froth	6	90	4
Biological sludge	0.5	94.5	5
Basin settlings	3	75	22
Storm silt	7	35	58
Filter backwash	11	66	23
Boiler soot and slag			100
Unleaded sludge	43	12	45

* aqueous waste

5.2.1 Crude Fractionation. The only significant waste generated by crude fractionation operations was the desalting sludge. This waste contains emulsified and at times free oil, ammonia (to reduce corrosion), phenols, and suspended and dissolved solids. A total of 19 refineries produced 113.9 t (dry basis) of desalting sludge in 1978.

5.2.2 Cracking Processes. Cracking processes include fluid catalytic cracking, coking and hydrocracking. The waste produced is the spent catalyst, and the catalyst and coke fines. The 18 plants that had fluid catalytic cracking units generated 2 929 t of spot cracking catalyst, the four plants with coking units had 226 t of waste, and the five refineries with hydrocracking units had 242.1 t of spot hydrocracking catalyst.

5.2.3 Alkylation. The alkylation process that uses sulphuric acid as catalyst generates aqueous waste of spent acid and caustic soda. The six refineries that were using this process produced 30.4 kt of spent acid (90% H_2SO_4) and 4.35 kt of spent caustic soda in 1978. The second type of alkylation process uses hydrofluoric acid as catalyst. Seven refineries were using this process and generated: 188 t of spent alumina (100% solid); 426 t of spent caustic soda, acid, and KOH (aqueous waste); three plants reported 201 t of acid oil; four refineries declared 120 t of neutralization pit sludges; and miscellaneous waste such as molecular sieve, spent clay, and silica which amounted to 35 t (reported by one refinery).

5.2.4 Conversion. Spent catalyst is the waste material generated by the three conversion processes (poly gasoline, hydrotreating and reforming). In 1978, 15 refineries produced 635 t of catalyst waste from the poly-gasoline process. Twenty refineries declared 182 t of hydrotreating catalyst, and 17 refineries reported 78.5 t of catalyst wastes from the reforming unit. Different types of catalyst waste amounting to 298.6 t were also reported by six refineries.

5.2.5 Treating Processes. Most of the waste generated by treating processes is spent caustic soda (aqueous). Eighteen refineries produced 18.0 kt of caustic phenolic waste in 1978. Fifteen refineries produced 5.88 kt of caustic sulphidic waste. Other caustic waste amounted to 8.57 kt (from nine plants). Spent acid which was generated by two plants and the annual amount was estimated at 61.98 t. Ten plants generated 219.9 t of diethanolamine/monoethanolamine (DEA/MEA) sludge. Solid waste generated by this process includes spent clay and sand, Claus catalyst and other wastes such as off-specification sulphur and filter cleanout. Ten refineries produced 392 t of spent clay and sand, and 113.6 t of Claus catalyst. Three plants declared 42 t of other types of wastes.

5.2.6 Special Processes. Special processes include BTX production (benzene, toluene, xylene), lube and grease, and asphalt production. Five refineries with BTX processes generated 114 t of spent clay (solids) and 65.8 t of glycol and solvent regeneration wastes (aqueous). The same number of plants reported the following annual waste amounts from lube, and grease production: 1.62 kt of slop oils, waxy sludge, off-specification lube, and kettle washing; 136 t of clay slurry; 49.9 t of waste grease and off-specification grease. Some of the waste from asphalt operation results from spills. Sixteen refineries reported 332.7 t of this type of waste. Six refineries produced 4.76 kt of off-specification asphalt. In addition, asphalt production generated 4.3 t of spent activated carbon, 12.7 t of cleaning waste, and 10.6 t of melt tank waste.

5.2.7 Effluent Treatment. The treatment of wastewater generates a variety of sludges that contain some oils and solids. The sludge from gravity oil-water separators is periodically removed from the bottom of the separator and contains oils, water, rust, sand and mud. Thirty-three refineries reported 5.58 kt of this type of sludge in 1978. Flotation froth is produced by the air flotation unit and contains mostly water with some oil, solids, and in some cases, chemical coagulants or flocculants. Thirteen refineries generated 13.1 kt of this froth. Biological sludge is continuously removed (at a low rate) from biological treatment systems to avoid build-up of excess activated sludge. The sludge contains a large quantity of water with microbial biomass, particulate, oils and dissolved products. Fourteen refineries generated 18.2 kt of this biological sludge. Eighteen refineries produced 8.48 kt of basin settlings. Storm silt accounted for 1.63 kt (for nine plants). Three refineries reported having 4.04 t of filter backwash waste. Miscellaneous wastes such as slop emulsions, and water sludge are also generated and were estimated at 369 t in 1978.

5.2.8 Water Treatment. Intake water is treated to various degrees according to the plant location. In 1978, lime solids and flocculation solids amounted to 16.9 kt from 22 plants. Cooling water tower sludge was estimated at 3.78 kt from 17 plants. Ten refineries reported 458 t of intake trash. Miscellaneous wastes, such as zeolite resin and filters, amounted to 177 t.

5.2.9 Tank Bottoms. Water and suspended solids in crude oil separate during storage. The water then accumulates with the solids under the oil, forming a bottom sludge. Finished product storage can also produce a leaded or unleaded sludge depending on the product stored. Leaded sludge was declared by 17 refineries in 1978 and amounted to 35.3 t. Unleaded sludge was estimated by 27 refineries and totaled 8.39 kt. Six refineries reported 1.14 kt of caustic/phenolic bottoms (aqueous waste).

5.2.10 Fuel Systems. Fuel systems generated 784 t of boiler soot and slag (14 refineries). This figure, however, does not include an estimated annual 502 t of this waste lost to the atmosphere.

5.2.11 Miscellaneous Wastes. Maintenance and shutdown operations also generate some wastes which were estimated to be 16.3 kt in 1978. General garbage accounted for 10.2 kt; metals, 934 t; oily wastes, 7.4 t; and spills reported by two refineries, 952 t.

5.3 Waste Disposal Practices

Disposal practices for oil refining wastes include: landfilling, landspreading, recovery-recycling, incineration, deep-well injection and others such as solidification and chemical fixation.

The proportions of refinery waste that were disposed of by various techniques in 1978 were:

	Total Waste		
	Based on the total Weight	Dry Basis	Aqueous Waste
Landfilling	35.7%	74%	
Landspreading	17.8%	15%	
Recovery/Recycling	29.7%	8%	72.4%
Incineration	6.9%	3%	3.3%
Deep-well Injection	1.4%		4.3%
Other Methods	8.5%		19.7%*

* treated and discharged with effluent

Another waste survey was conducted by PACE in 1985 (20). This survey was designed to identify the various wastes generated by the petroleum refining industry, and the waste disposal methods being used. The wastes were not quantified but were divided into three categories: small (0 to 1 t/year); medium (1 to 100 t/year); and large (over 100 t/year). A total of 55 different wastes were identified. Recovery, landspreading, and landfilling were the major methods being used to reduce the volume or dispose of wastes generated. Deep-well injection and incineration were used for only a small amount of wastes.

5.3.1 Landfilling. Landfilling is predominantly an anaerobic (without oxygen) system in which solid wastes or sludges are compacted and covered with a layer of soil. Various precautions can be taken to protect groundwater, such as: selecting a suitable surficial geology; using impermeable barriers (e.g., clay or synthetic polymeric materials); providing a leachate collection and treatment system; and groundwater monitoring. Certain chemicals present in some landfills can change the property of clay, rendering it highly permeable (19). The degree of landfill sophistication depends on the type of waste being disposed.

According to the 1978 survey by PACE, 69.8 kt of wastes were landfilled that year. More than 80% of this waste was made up of general garbage, miscellaneous inert shutdown and maintenance wastes, lime and flocculation solids from water treatment, and biological sludge from effluent treatment.

5.3.2 Landspreading. Landspreading, also known as landfarming or land treatment, is a waste disposal method that consists of applying certain types of petroleum sludges to the upper soil layers so that soil microorganisms degrade the organic constituent of the waste, reducing both waste mass and toxicity. The sludge is first applied evenly on the landfarm and allowed to dry. Then it is mixed into the top 15 to 20 cm of soil with machinery such as a disk harrow or rotary cultivator. This mixing step is repeated every two to four weeks until biodegration is complete so that the microorganisms receive sufficient oxygen and the sludge is evenly mixed. Small quantities of fertilizer can be added to improve the efficiency of hydrocarbon biodegradation. Reapplication of sludges can be undertaken after biodegradation has been completed. Environmental monitoring and controlled application are required to protect groundwater and surface water runoff.

The use of landspreading is increasing as an alternative to landfilling for biodegradable refinery wastes. In 1978, 34.5 kt of waste were disposed of by this technique. The majority of the waste originated from effluent and water treatment and from oily tank bottom sludges.

5.3.3 Recovery/Recycling. Recovery is the reclamation of some valuable constituents in the waste through reprocessing (e.g., distillation). Recycling is when the waste is being directly reused as raw material or with very minor modification. Whenever economically favourable, some wastes are recovered for reuse either within the refinery or for sale to others. In 1978, refineries recovered a total of 58.1 kt of catalysts, alkylation acid, spent caustic product, and scrap metal. This figure does not include the very large quantities of oils recovered in slop systems and the effluent treatment system. Some research is being done on recovering oil from oily refinery sludges.

5.3.4 Incineration. Incineration is mainly carried out off-site by a contractor when other alternatives are not possible. Liquid wastes are usually introduced into incineration chambers through burner jets, and depending on their heat value, auxiliary fuel may be required. Complete combustion occurs when the organic material has been converted mostly into water and carbon dioxide. Other products such as sulphur oxides and nitrogen oxides may be formed. Inorganic compounds are concentrated in the residue (bottom ash and fly ash). Unless incineration is carefully designed and operated, intermediate products could be formed. Some of these products may be very hazardous. In 1978, 13.8 kt of refinery wastes were incinerated. This included mostly effluent treatment biological sludge and flotation froth, and spent caustic products.

5.3.5 Deep-well Injection. Disposal of some types of aqueous wastes by deep-well injection is permitted only in Alberta. Usually, the waste is pre-treated and pumped into suitable geological formations, at depths ranging from 300 to 3600 metres, to confine the waste. The injection must be done under controlled conditions (injection pressure, proper equipment design, appropriate site selection) to prevent lateral or vertical migration of the waste which could lead to groundwater contamination. Most of the waste injected in 1978 was spent caustic products from treating processes and some of the waste was stripped sour water and desalter effluent. The total waste that was deep-well injected in that year was 2.7 kt.

5.3.6 Other Methods. Other disposal practices may include solidification and lagooning. Solidification or chemical fixation is a method whereby chemicals are added to the waste to form a solid in order to limit the solubility or to detoxify any hazardous constituents contained in the waste. This method has only been used sparingly as a treatment method for oily waste. Lagooning is only a temporary solution and requires a large area of land to store the waste (now rarely used). In the 1978 survey, 16.8 kt of wastes (mostly from treating processes) were disposed of by other or unspecified methods. Two-thirds of this waste was handled in effluent treatment systems.

5.4 Environmental Concerns Associated with Disposal Methods

5.4.1 Landfilling. A landfill is a potential source of gaseous emissions, and surface water and groundwater contamination from leachate migration. The environmental risks can be minimized through a number of measures which include:

1) a proper site location (area of low rainfall, remote from drinking water wells and high quality groundwater, soil with low permeability, and other criteria);
2) a proper landfill design (liner, soil barrier, drainage ditch, and others);
3) characterization of waste to provide pretreatment and/or segregation (to avoid chemical reactions in the landfill);
4) an adequate recovery/treatment/disposal system for landfill leachate and gas; and
5) a long-term monitoring system for groundwater and air quality around the site.

The level of stringency associated with these measures increases when dealing with hazardous wastes and decreases when dealing with non-hazardous wastes.

5.4.2 Landspreading. As with any disposal method that involves direct contact of waste with soil, improper operating procedures can lead to surface water and groundwater contamination, odours and site vegetation destruction. The following factors should be considered to minimize environmental risks: biodegradation property of the waste and the soil; site hydrology; weather conditions; heavy metal content of the waste; and application rates. In addition, proper surface runoff control and groundwater (and air quality if necessary) monitoring are required along with adequate nutrient additions.

The limited information available on vapour release at refinery landspreading sites suggests that hydrocarbon emissions are not significant. Metals contained in the waste will accumulate in the soil rather than biodegrade. The buildup of chromium, lead, zinc, nickel, copper and vanadium represents an environmental concern and may limit the useful treatment life of a refinery landfarm.

The Wastewater Technology Centre of Environment Canada has been conducting research studies for PACE to assess the fate of polynuclear aromatic hydrocarbons (PAH) when disposed of in soil (21). Another study is currently underway to confirm the laboratory results obtained in the field. These hydrocarbons are a group of organic chemicals found in a number of industrial wastes (including those from oil refineries). Some of them are toxic, carcinogenic and/or mutagenic and those with higher molecular weights persist in soil and sediments and bioaccumulate in aquatic organisms. The results of the laboratory studies indicate that:

- depending on the concentration of PAH in the waste, and on the rate and frequency of application, PAH may accumulate in the soil;
- biodegradation of PAH (benzo(α)pyrene) in a landfarm soil was higher than in agricultural soil due to a higher microbial population and carbon content, and to prior acclamation of microorganisms, and the degradation is enhanced by the addition of nutrients (nitrogen and phosphorus);

- degradation of recalcitrant (high molecular weight) PAH compounds via appropriate and controlled land application may be possible; and
- further studies are required to identify land application practices that would maximize biodegradation of PAH, and to determine the toxicity and fate of possible metabolites.

5.4.3 Incineration. The environmental risks associated with incineration are air emissions, solid residues, and water pollution.

Air emissions include particulate and gaseous products of combustion. These may be controlled with afterburning (to reduce the formation of uncombusted organics that may be carcinogenic), precipitating, scrubbing and/or filtration systems (for particulate and combustion products).

Ash, the solid residue produced from combustion, does not normally contain organic contaminants but may contain various salts, metals, and other non-combustibles and must receive proper disposal (generally to an approved landfill).

Wet scrubbing systems for gas cleanup and water used for ash quenching produce liquid effluent that is acidic or alkaline and may contain high concentrations of salts or other inorganics. These liquid effluents must be treated before disposal to prevent water pollution.

5.4.4 Deep-well Injection: Deep-well injection represents an ultimate disposal method for certain liquid wastes (e.g., acids, bases, alcohols, solvents and salts). Groundwater contamination can result from geological failure, mechanical failure or failure to identify waste properties. Geological failures are the most serious and can result in waste migration either laterally or vertically beyond the planned disposal formation. These failures are caused by improper site selection or excessive injection pressure. Mechanical failures are due to poor injection techniques that result in equipment failures. When waste properties are not well defined before injection a reduction or loss of formation permeability (caused by physical plugging, chemical or biological reactions) may occur, allowing migration of waste. All these failures can be prevented with proper site selection, operating techniques, and waste testing under simulated formation conditions to determine its properties.

5.4.5 Solidification. According to current research, waste that has been solidified is not subject to significant leaching of inorganic compounds. More research is required, however, to determine if low leachability persists under weathering effects and after long-term storage in a landfill. Care should be given to proper disposal of this waste to avoid contact with incompatible wastes and potential leaching of contaminants. This will reduce the potential for surface and groundwater contamination.

6 STUDIES PERTAINING TO THE INDUSTRY

6.1 Trace Contaminants in Petroleum Refinery Effluents

Since the mid-seventies, Environmental agencies in the U.S. and Canada and some industrial associations (API* and PACE) have been focussing on trace contaminants in industrial effluents. In Canada, PACE and Environment Canada have commissioned a number of studies to investigate the possible presence of trace contaminants (using the U.S. EPA** priority pollutant list) in refinery effluents (22, 23, 24).

Most of the metals on the U.S. EPA list were detected in intermediate treatment waters and were detected less frequently and at reduced concentrations in final effluents. The concentrations of the following priority pollutant metals were not considered significant in terms of known regulations: antimony, arsenic, cadmium, lead, mercury, nickel and selenium. The priority pollutant metals beryllium, silver and thallium were never detected. Zinc and chromium were usually detected in final effluents and often at concentrations above 100 parts per billion. Eighty percent of the organic compounds on the U.S. EPA priority pollutants list were not routinely detected in refinery wastewaters. Most of the compounds that were routinely detected are normally contained in crude oil. A summary of the organics that were detected is provided in Table 32.

A well-operated wastewater treatment system, that uses the best practicable treatment technology, is very efficient at removing or sometimes eliminating organic priority pollutants from waste streams, while most metals are concentrated in the sludges. Some of the priority pollutants were, nonetheless, detected in final effluents. Conventional parameters such as oil and grease, total organic carbon, suspended solids, and total phenols provide a good indication of the effectiveness of refinery wastewater treatment.

The priority substances that were consistently or frequently detected in refinery effluents are: chromium, zinc, benzene, toluene, ethylbenzene, naphthalenes, and phenols. Phthalate esters and polynuclear aromatic hydrocarbons were occasionally detected in refinery effluents at very low concentrations. Numerous other organic compounds were also detected; most of them derivatives of the above organics. The concentrations of trace substances found in refinery effluents are generally below the water quality criteria published by various regulatory agencies which include: the

---

* API - American Petroleum Institute
** U.S. EPA - United States Environmental Protection Agency

TABLE 32 SUMMARY OF ORGANIC SUBSTANCES DETECTED IN REFINERY WASTEWATERS (22)

1. FROM PRIORITY POLLUTANT LIST	
Compounds not detected	- most of the volatile halogenated compounds; - Polychlorinated Terphenyls - Polybrominated Biphenyls - Chlorophenols and Nitrophenols - Nitrosamines - Haloethers
Compounds rarely detected and not considered to be associated with the refinery process	- Polychlorinated Biphenyls - Halogenated compounds - e.g., Chloroform, Dichloromethane
Compounds frequently detected in ITW* and occasionally in final effluents at low (low ppb) concentrations	- Phthalate esters - Polynuclear Aromatic Hydrocarbons
Compounds detected at high concentrations in ITW* and frequently or consistently detected but at reduced concentrations in final effluents	- Benzene, Toluene and Ethylbenzene (aromatic compounds) - Naphthalene - Phenol
2. ADDITIONAL SUBSTANCES	
Consistently detected in effluents	- Aliphatic Hydrocarbons
Frequently detected in effluents	- Alkyl-substituted Benzenes, Naphthalenes, Phenols
Occasionally detected in effluents at low ppb concentrations	- Alkyl substituted Polynuclear Aromatic Hydrocarbons - Mercaptans - Thiophenes - Ketones - Acetone - Fatty acids

*ITW = Intermediate Treatment Waters

Canadian drinking water guidelines; the U.S. EPA criteria for human toxicity and domestic water supplies; the U.S. EPA criteria for aquatic toxicity; the British Columbia effluent criteria; and those of the World Health Organization. The only substances that did exceed criteria on occasion were: chromium, benzene, polynuclear aromatic hydrocarbons, phthalate esters and phenols. It should be stressed that the criteria were exceeded only occasionally. For example, chromium exceeded the British Columbia effluent criterion of 0.20 mg/L in five out of a total of 29 samples. Benzene exceeded the U.S. EPA drinking water criterion of 0.007 mg/L in eight out of 29 effluents of total outfalls analyzed. It should be noted that in all cases effluent samples were taken at outfalls which are normally diluted with once-through cooling water (dilution factor of approximately 10).

Within the wastewater treatment system, the most significant mechanisms for reducing organic priority pollutants are oil and grease removal in the API and the dissolved air flotation units followed by biological biodegradation. Adsorption to sludge or volatilization to the atmosphere appear to be minor removal mechanisms. Some sludges (particularly oily sludges) can contain appreciable concentrations of priority pollutants, both metals and organics, and more research is required concerning the disposal of these sludges.

6.2 Analytical Methodology for the Effluent Regulations and Guidelines

Since the promulgation of the federal regulations and guidelines in 1973, the analytical methodologies for some of the regulated parameters (oil and grease, phenols, and ammonia nitrogen) have evolved. Two additional editions of the APHA method have been published and the 16th edition is being finalized. Some refineries, as specified by provincial requirements, have been using the 14th or 15th editions to analyze their effluents. In an attempt to assess the different methods, a joint PACE-Environment Canada study was conducted to compare the analytical results that would be obtained with the 13th and 15th editions. Twenty samples were collected from the effluent of six refineries, on different days for each refinery. Three laboratories were selected to make the analyses, and each one was responsible for sampling and analyzing effluent from two refineries. Each sample was divided into quarters, and two quarters were analyzed with the method from the 13th edition and two quarters with the method from the 15th edition.

The results for each parameter can be summarized as follows: oil and grease did not show any significant difference between the two methods; for phenols, the 15th edition provided higher values that varied between 0 and 120%; and for ammonia nitrogen, the results for five refineries were 2 to 34% higher with the 15th edition and one refinery had results that were 237% higher with the 15th edition. For both phenols and ammonia nitrogen, the correlation between the results of the 13th and 15th editions varied greatly between refineries; the 15th edition values were generally higher than those of the 13th. For oil and grease, there was much less variation between the correlations from each refinery and the overall results indicated little difference between methods. Each laboratory, however, experienced difficulties with the newer method and had to adapt the method to make the analysis. Despite these changes, two laboratories reported problems with the reproducibility of the method from the 15th edition.

Given the variability of the results and the analytical problems encountered with the 15th edition method, it is very difficult to draw any conclusions. No unique correlation was found between the two methods apart from generally higher results when using the 15th edition method for phenols and ammonia nitrogen.

6.3 Groundwater

Groundwater may be defined as subsurface water that occurs in a saturated zone below the ground surface and moves (from millimetres to metres per day) in the pores between sand, rock or soil, or in geologic formations that are fully saturated. Subsurface permeable formations that yield significant amounts of water to wells and springs are known as aquifers. In Canada, aquifers underlie all the populated regions of the country. Twenty-six percent of the population depend on groundwater for domestic water supply (this percentage is higher in the Maritimes and in Saskatchewan), and 38% of the municipalities derive their water supply partially or exclusively from groundwater. In addition, agriculture uses large amounts of groundwater.

Groundwater is essentially under provincial jurisdiction. When used as a drinking water supply, groundwater is subject to provincial drinking water standards. However, some provinces are establishing levels that will be used to determine whether or not groundwater is contaminated and in need of cleanup.

6.3.1 Sources of Groundwater Contamination. Contamination of groundwater can occur from human activities such as: disposal sites (e.g., landfill) for industrial and municipal wastes; agricultural practices (including pesticide application); leaking underground storage tanks (mostly from service stations); septic tanks; road salting; land disposal of waste (oil and gas production); leaks and spills; deep-well injection of waste; mining waste; and others. Although at this time the extent of contamination has not been related to specific sources, it is believed that the four major sources of groundwater contamination are: agricultural practices, leaking underground storage tanks, septic tanks, and road salting.

Although petroleum refineries do not constitute major sources of groundwater contamination, there is a potential for local contamination surrounding the site. As discussed in previous sections, the sources of potential groundwater contamination from petroleum refining operations are: spills and leaks of hydrocarbons (or other chemicals), land disposal of wastes (landfill, landspreading), lagoons (if not properly lined) and deep-well injection of waste. Landfills for refinery waste, however, are normally located off-site and are part of the local government's waste management system.

6.3.2 Fate of Dissolved Organics in Groundwater. Gasoline entering the groundwater system through spillage (on the refinery site) or leaks from underground storage tanks (such as service stations) poses a serious threat to groundwater quality. The most soluble hydrocarbon components of gasoline: benzene, toluene, ethylbenzene and xylene (BTEX) are among those of greatest environmental concern. These compounds can impart odour and taste to water at very low concentrations (a few micrograms per litre). Benzene is the most soluble, and represents a particular concern because of its carcinogenic effect on man. The undissolved gasoline phase on top of the saturated zone can be recovered relatively easily; the dissolved organics (BTEX), are more difficult to clean up. At low concentrations, most of the BTEX will normally be biodegraded by aerobic (using oxygen) bacteria that are present in groundwater. The amount of dissolved oxygen available to the bacteria will limit BTEX biodegradation. Where large volumes of groundwater are contaminated by gasoline, the oxygen will rapidly be depleted and BTEX will persist. Although some oxygen can be brought to the area of contamination through natural mixing processes (dispersion), this may be inadequate to significantly reduce BTEX. The remedial measure used in such cases is the withdrawal and treatment of the contaminated groundwater or the injection of oxygen or other oxidants to the groundwater (in situ).

Research studies jointly supported by PACE and Environment Canada are assessing other in situ remedial measures for BTEX-contaminated groundwater (25, 26). Laboratory tests indicated that biodegradation of BTX (benzene, toluene, xylene) occurs in the presence of oxygen or nitrate (a bacteria nutrient) without the accumulation of potentially harmful organic intermediates. A field injection experiment is currently underway to confirm the laboratory test results for nitrate addition to gasoline contaminated groundwater.

7 DECOMMISSIONING OF INDUSTRIAL SITES

As shown in Table 33, a total of 14 refineries have been shut down over the past ten years (1976-1986). These plants have been either mothballed, partially shut down, or decommissioned (or are in the process). Mothballing is a shutdown with the intent of future reactivation; in a partial shutdown, an area of the plant such as the processing area is shut down, while an area such as the tankfarm is converted into a product marketing terminal; decommissioning is a permanent shutdown and involves the dismantling of equipment and the preparation of the site for future use.

TABLE 33 LIST OF REFINERY CLOSURES (1976-1986)

Company	Location	Capacity m^3/d	Closure Date
B.P. Canada	Anjou, Quebec	11 900	May 1983
Esso Petroleum	Montreal, Quebec	12 600	Oct. 1983
Gulf Canada	Point Tupper, Nova Scotia	12 600	Sept. 1980
Gulf Canada	Kamloops, B.C.	1 510	May 1983
Gulf Canada	Calgary, Alberta	2 050	Dec. 1983
Gulf Canada	Montreal, Quebec	11 770	Jan. 1986
Husky Oil*	Lloydminster, Alberta	1 900	Mar. 1983
Petro-Canada	Come-by-Chance, Nfld.	15 900	Mar. 1976
Shell Canada	Oakville, Ontario	7 000	July 1983
Shell Canada	Winnipeg, (St. Boniface) Manitoba	4 700	Oct. 1983
Texaco Canada	Edmonton, Alberta	4 450	May 1984
Texaco Canada**	Port Credit, Ontario	7 950	Jan. 1979
Texaco Canada	Montreal, Quebec	11 800	Sept. 1982
Ultramar Canada	Holyrood, Nfld.	12 000	June 1983

* This is the old Husky refinery; a new one was built (commissioned in 1983) on the same site.

** The BTX units continued to operate after January, 1979.

7.1 Regulatory Requirements

The jurisdiction for decommissioning activities is primarily provincial. While certain provincial and federal environmental regulations regarding discharges of wastewaters to surface waters and the operation of landfill sites can be applied to the cleanup of industrial plant sites, only the province of Ontario has developed guidelines specific to the decommissioning of industrial plant sites. Quebec and Alberta are in the process of developing guidelines, and current closures are dealt with on a case-by-case basis. The federal government, in cooperation with Ontario, Quebec, and Alberta and industry associations (chemical and petroleum - including PACE) is developing methodologies that can be used in establishing site-specific cleanup criteria for decommissioned industrial sites. This work is being conducted for the Waste Management Committee of the Canadian Council of Resource and Environment Ministers. The need to establish cleanup criteria for decommissioned sites was identified as a first priority at two workshops on decommissioning that were sponsored in 1985 by the federal government, by three provinces and three chemical and petroleum industry associations.

The Ontario guidelines (27) used for refineries that are being decommissioned address various environmental aspects of decommissioning, such as:

1) on-site waste treatment facilities;
2) hydrogeological and soil investigations;
3) disposal of materials accumulated on site; and
4) air quality and land usage.

The guidelines specify that, during decommissioning, the discharges from on-site treatment facilities cannot exceed the levels specified in the plant's operation license. The items to be included in the soil and hydrogeology investigation program are outlined, and it is required that contaminated soils (levels exceeding phytotoxicological guidelines) be cleaned up and disposed of properly. Materials that have accumulated on-site cannot be left on-site but may be sold or disposed of properly. The degree of final soil decontamination will depend upon the future use of the land.

7.2 Environmental Aspects of Decommissioning

A guide to the environmental aspects of decommissioning industrial sites was prepared by Monenco Consultants Ltd. for Environment Canada (28). The guide was aimed at oil refineries, and natural gas processing and chemical plants but the principles may be applied to other industries. The highlights of the report are discussed in the following.

During the operating life of a plant, there is an accumulation of liquids, solid wastes, sludges and sediments from wastewater treatment and product storage. In addition, spills and leaks of process chemicals, products and by-products may have caused contamination in the area of the plant, soils, surface water and groundwater. As a result, a cleanup program may be required as part of decommissioning activities such as dismantling and removing equipment and buildings. The purpose of this program is to make the site environmentally safe for the proposed future use.

A number of steps should be carried out to identify environmental concerns and to clean up the site. After the decision to decommission a plant is made, a plant site assessment should be conducted to identify potentially contaminated areas and to optimize the sampling and analytical program. This involves information gathering on the operating history of the plant (such as waste management practices and chemical handling over the operating life of the plant). The next step is the site investigation which consists of sampling and analyzing the soil, groundwater, and possibly surface water to identify the extent of contamination. This assessment should be conducted in phases with an initial reconnaissance testing program followed by (if required) detailed testing in areas of concern. At this stage cleanup criteria should be developed for the particular conditions of the site to determine the extent of cleanup required for the safe re-use of the site. After cleanup and reclamation options are selected, the actual cleanup of the site is conducted. During the cleanup, provisions for worker safety and health, and collection and treatment of wastewaters generated must be considered. In addition, confirmatory sampling and analysis are required during cleanup to ensure the effectiveness of the program. When cleanup activities are completed, confirmatory sampling and analysis are again required to ensure that there are no residual contaminants in excess of cleanup criteria. Finally a long-term monitoring program may be required to measure the effectiveness of the cleanup program. It should be noted that the degree of the site contamination will dictate the level of detail required in each step.

The environmental regulatory agencies will be involved throughout the decommissioning program to ensure that the site is cleaned up to a level that will provide long-term environmental protection and will be-safe for future users. Approvals from regulatory agencies may be required at each step.

The concerns of the interested public should be addressed in the development and implementation of the decommissioning plan for the successful conclusion of the cleanup program. In addition, by keeping concerned members of the public informed of the cleanup progress, misconceptions and concerns will be dissipated, facilitating the completion of the various activities of the program.

Some preventative measures can be taken during the operation of the plant or prior to construction to reduce the cost and complexity of eventual site cleanup. For an existing plant, changes in operating procedures will have a direct effect on the extent of cleanup required. These include: proper waste management; groundwater and surficial soil monitoring to detect potential contamination and implement mitigation before problems develop; keeping detailed inventories of chemicals and waste disposal practices; and preparation of an annual environmental information report. For new plants, site decommissioning factors should be considered at the site selection stage, including the ability of the proposed plant site to degrade, neutralize, and contain contaminants resulting from plant operations. These factors should also be considered while designating the location of the various processing facilities. Design, operating, and waste management practices are features that can be built into a new facility to prevent or contain losses. Regular environmental auditing of all internal operations and procedures that may have environmental implications is a growing practice in the industry and reflects a proactive and progressive approach to sound environmental management. Environment Canada endorses and encourages environmental auditing.

In a 1984 limited survey, 37% of the refineries had an environmental auditing program. To further promote its use, PACE conducted an environmental auditing workshop in November 1984, and followed with an "Environmental Auditing Rating System Project" the same year. One objective of this work is to develop standards for performance measurement in areas where standards are inadequate or do not exist.

8 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations following are based on an assessment of: information collected through industry surveys performed by PACE and Environment Canada, or through federal regulatory and guidelines requirements; explanations reported by the oil refineries on problems encountered in operating their wastewater treatment systems; environmental studies conducted for PACE and Environment Canada over the past few years; and current pollution abatement technologies. No detailed feasibility studies were made and no consideration was given to economic and legislative limitations nor local requirements. Given these restrictions, the following conclusions and recommendations can be drawn from the study.

8.1 Conclusions

1) Most (96%) of the carbon monoxide emissions from refineries originate from catalytic cracking units. Twenty of these units (out of 24) are equipped with CO boilers which reduce CO emissions.

2) Sulphur dioxide is mostly emitted from boilers, process heaters, and catalytic cracking units. Twenty refineries recover the sulphur from hydrogen sulphide streams, mostly using the Claus process (two- or three-stage), and four refineries have additional recovery with tail gas units.

3) Storage tanks are the major source of hydrocarbon emissions (86%). The cone-roof tanks represent only 11% of the storage capacity, although they were responsible for 72% of the hydrocarbon emissions from all the storage tanks. Emissions from loading facilities were not assessed; however, splash loading has been almost eliminated and replaced by submerged loading to reduce vapour losses. Newer installations use bottom loading, which further reduces the emissions.

4) Fuel combustion was responsible for most of the nitrogen oxides emissions.

5) The majority (56%) of the particulate emissions are from the regenerators of the catalytic cracking units. Twenty-four refineries have control systems to reduce these emissions and most of them use internal cyclones (two- or three-stage). Two of these refineries also use electrostatic precipitators.

6) The refineries continue to improve their effluent qualities from year to year although some deposits still exceed the regulations and guidelines limits.

7) New refineries benefit from the most up-to-date wastewater treatment technology and generally have better performances than the older refineries.

8) Since 1972, there has been a general downward trend for the net discharges of all the parameters. If the 1983 discharges are compared to the 1980 levels, reductions ranging from 21% to 53% are found for most parameters except sulphide, which had

a 26% increase (but was still below the limit). The reductions were not entirely caused by the 20% drop in production.

9) Most of the refineries have a secondary treatment system or send their effluents off-site for secondary treatment.

10) Under good operating conditions, the wastewater treatment systems existing at the refineries should easily meet the limits prescribed in the federal regulations and guidelines, and attain levels that are well below the limits.

11) Generally, the regulations and guidelines limits are exceeded when the wastewater treatment system is under upset conditions (overloaded) or has mechanical deficiencies.

12) Under good operating conditions, the best practicable wastewater treatment technology (used in most refineries) is very efficient in removing or sometimes eliminating organic priority pollutants from waste streams, while most metals accumulate in the sludges.

13) The concentrations of trace substances found in effluents from well-operated systems are generally below water quality criteria published by various regulatory agencies. A few exceptions were noted.

14) Analytical problems (results were not reproducible) were encountered when using the 15th edition of the APHA method to analyze for oil and grease, phenols and ammonia nitrogen in refinery effluents.

15) No single correlation can be obtained between the analytical results of the 13th and 15th editions of APHA, although the 15th edition appears to produce higher results for phenols and ammonia nitrogen.

16) Based on laboratory work, biodegradation of BTX in groundwater can be achieved with the addition of oxygen or nitrate. This is being verified in the field.

17) A 1978 industry survey indicated that the most common waste disposal method used by refineries was landfilling, followed by recovery/recycling and landspreading. There was an indication, however, that landspreading was increasing as a substitute for landfilling.

18) Based on laboratory studies, there is a potential for biodegrading recalcitrant PAH through appropriate and controlled land application. Another study is underway to confirm the laboratory results in the field.

19) Environmental risks associated with each waste disposal method can be minimized if the methods are used under controlled conditions.

20) The determination of the need and extent of cleanup for a decommissioned industrial plant (such as a refinery) requires the sequential completion of cleanup activities in order to ensure that all the activities are performed and to permit the successful cleanup of the site in a cost-effective manner.

8.2 Recommendations

1) The refineries should consider the following measures to reduce their air emissions:

   - use of CO boilers at the remaining four refineries with catalytic cracking units;

   - desulphurization of "heavy bottoms" or blending of this fuel with low-sulphur, light oil to reduce sulphur dioxide emissions (further reductions can be achieved by the use of tail gas units);

   - installation of vapour recovery systems connected to the vents of cone-roof tanks as a temporary solution until they are replaced by tanks with floating roofs;

   - venting of pumps and compressors to flares (or equivalent) to reduce hydrocarbon emissions; use of mechanical seals of the single and double type and their proper maintenance to reduce leaks;

   - modified combustion techniques (controls of operational parameters) and changes in furnace design for new facilities to minimize the formation of nitrogen oxides;

   - use of smokeless flare systems and, where necessary, electrostatic precipitators, and the use of natural gas (if possible) as an alternative fuel in boilers and heaters in order to reduce particulate emissions; and

   - collection of waste gases containing malodorous compounds and recovery or combustion of these gases (one option would be to send them to the sulphur recovery plant).

2) The refineries should report all tests required by the federal regulations and guidelines. It should be noted that even though the provincial reporting requirements may be different from the federal requirements, both must be reported to the provincial government.

3) The refineries should also declare a revised reference crude rate when the arithmetic mean of the stream day crude rates during two consecutive months is less than 85% of the last RCR declared.

4) Wastewater treatment systems should be kept in good operating condition and optimized to remove traditional and organic priority pollutants (which are normally reduced with the traditional ones). To achieve this goal, it is suggested that training (or refresher) courses be provided to operators of the wastewater treatment system and that operating conditions be defined to optimize removal of biodegradable priority pollutant compounds.

5) The federal refinery effluent regulations and guidelines should be reviewed and updated to reflect: changes in the industry, current analytical methodology, and changes in focus toward toxic chemicals.

6) The industry should review its waste management handling and disposal practices, and identify optimum waste treatment techniques and emerging technologies to minimize and eliminate potential effects on the environment.

7) Further studies should be undertaken to identify land application practices that would maximize biodegradation of PAH compounds and to determine the toxicity and fate of possible metabolites.

8) Further studies should also be carried out to assess the potential for groundwater contamination from landspreading and landfilling of refinery waste.

9) To improve the environmental performance of the industry and thereby reduce the cost and complexity of eventual site cleanup during decommissioning a number of preventive measures should be taken, such as:

   - proper management of wastes with emphasis on spill and loss prevention;

   - groundwater and surficial soil monitoring to detect contamination and implement mitigation before problems develop;

   - maintenance of inventories of chemicals and waste disposal practices;

   - preparation of an annual environmental report; and

   - consideration of site decommissioning factors at the site selection stage, for new plants. These include the ability of the proposed plant site to degrade, neutralize, and contain contaminants from plant operations and should also be considered in designating the location of the various processing facilities. Design, operating and waste management features and practices to prevent or contain losses also can be built into a new facility.

10) Environmental auditing, a powerful environmental management tool, should be encouraged and its use promoted.

REFERENCES

1. Environment Canada, "Petroleum Refinery Effluent Regulations and Guidelines", Water Pollution Control Directorate, Report EPS 1-WP-74-1 (January, 1974).

2. Fisheries and Oceans Canada, Fisheries Act, R.S.C. 1970, c. F-14 (1970).

3. Federal Government, Access to Information Act, s.c. 1980-81-82-83 c. 111.

4. Environment Canada, Clean Air Act, 1970-1971, c. 47 Canada Gazette (November 10, 1971).

5. Environment Canada, National Ambient Air Quality Objectives, Part I, Canada Gazette (December 16, 1972).

6. Montreal Urban Community, Air Purification, By-law 44 (December 1978).

7. Alberta Environment, Clean Air Act, RSA, 1980 c. C-12 (1980).

8. Department of Lands, Forests, and Water Resources, "Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia", Water Resources Service (March, 1974).

9. PACE, "Canadian Petroleum Refineries Atmospheric Emission Survey 1983", PACE Report No. 85-1 (November, 1985).

10. American Public Health Association (APHA), Standard Methods for the Examination of Water and Wastewater, 13th edition, published jointly by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation (1971).

11. Environment Quebec, "Environment Quality Act - Petroleum Refineries Liquid Effluents", Quebec Official Gazette, 109, No. 46 (November 9, 1977).

12. Environment Canada, "Pollution Abatement Review with Respect to Heavy Crude Oil Upgrading, Synthetic Crude Use at Refineries, Increased Natural Gas Processing, and Liquefied Natural Gas Facilities", (unpublished manuscript) IP-2 (August, 1982).

13. APHA, Standard Methods for the Examination of Water and Wastewater, 14th edition, published jointly by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation (1975).

14. APHA, Standard Methods for the Examination of Water and Wastewater, 15th edition, published jointly by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation (1980).

15. Ministère de l'environnement, Gouvernement du Québec, "Solid Waste Management Regulation", Environment Quality Act (1978).

16. Ministère de l'environnement, Gouvernement du Québec, "Hazardous Waste Regulation", Environmental Quality Act (July 30, 1985).

17. PACE, "The Significance of Trace Substances in Petroleum Industry Sludges Disposed of on Land: A Literature Survey", PACE Report No. 83-2 (May, 1983).

18. PACE, "Canadian Petroleum Refining Industry Waste Survey" PACE Report No. 80-4 (October, 1980).

19. Morrison, A., "Hazardous Waste Landfills: Can Clay Liners Prevent Migration of Toxic Leachate?", Civil Engineering, pp. 60-63 (July, 1981).

20. PACE, "Waste Management Guidelines for Petroleum Refineries and Upgraders", PACE Report No. 86-2 (November 1986).

21. PACE, "The Persistence of Polynuclear Aromatic Hydrocarbons in Soil", PACE Report No. 85-2, prepared by the Wastewater Technology Centre of Environment Canada (November, 1985).

22. PACE, "A Survey of Trace Substances in Canadian Oil Refinery Wastewaters and Sludges - A Summary Report", PACE Report No. 85-8, prepared for PACE and Environment Canada (December, 1985).

23. PACE, "Evaluation of the Variability of Trace Organic Substances in Petroleum Refinery Effluents", PACE Report No. 85-6, prepared for PACE and Environment Canada (December, 1985).

24. PACE, "Fate and Transformation of Selected Trace Organics in Refinery Wastewater Treatment", PACE Report No. 85-7, prepared for PACE and Environment Canada (December, 1985).

25. PACE, "The Behaviour of Soluble Petroleum Product Derived Hydrocarbons in Groundwater - Phase I", PACE Report No. 85-3 (November, 1985).

26. PACE, "The Behaviour of Soluble Petroleum Product Derived Hydrocarbons in Groundwater - Phase II", PACE Report No. 86-1, prepared for PACE and Environment Canada (April, 1986).

27. Ontario Ministry of the Environment, "Guidelines for the Decommissioning (shut down) of Major Industrial Sites in Ontario" (June 1984).

28. Environment Canada, "Guide to the Environmental Aspects of Decommissioning Industrial Sites", unpublished manuscript IP-32 (May, 1985).

BIBLIOGRAPHY

1. Gary J.H. and G.E. Handwerk, "Petroleum Refining Technology and Economics" second edition, Marcel Dekker Inc. (1984).

2. Alberta Environment, "Basis for Approval of Industrial Plants in Alberta", Standards and Approvals (July, 1983).

3. Environment Canada, Environmental Protection Service, "Petroleum Refinery Technology and Pollution Control", Seminar (October 2-4, 1974).

4. Jones H.R., "Pollution Control in the Petroleum Industry", Noyes Data Corporation (1973).

5. Environment Canada, Petroleum Refinery Compliance Reports, prepared by the five regional offices, unpublished documents.

6. Environment Canada, Environmental Protection Service, "Status Report on Abatement of Water Pollution from the Canadian Petroleum Refining Inudstry -1980", Water Pollution Control Directorate, Report EPS 3-WP-83-3 (March, 1983).

7. PACE, "Landspreading of Sludges at Canadian Petroleum Facilities", PACE Report No. 81-5A (December, 1981).

8. Reid Crowther & Partners Limited, "Hazardous Wastes in Northern & Western Canada - The Need for a Waste Management Strategy", Volume 2, Technology Review, report prepared for Environment Canada in Association with the Governments of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Yukon and Northwest Territories (December, 1980).

9. Ontario Waste Management Corporation, System Development Project, "Generic Process Technologies Studies", Proctor & Redfern Limited (August, 1982).

APPENDIX A

COMPARISONS OF PROVINCIAL AND FEDERAL LIMITS FOR COMMON POLLUTANTS IN REFINERY WASTEWATERS

TABLE A-1 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Oil & Grease

		Maximum Deposits lb/10^3 bbl·d^{-1} of crude oil				
Region	Status	Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery - existing refinery that is altered or expanded		3.0	5.5	7.5	
	- existing refinery, unaltered portion		6.0	11.0	15.0	
Quebec	- new		3.09	5.51	7.50	
	- existing		6.17	11.0	15.0	
Ontario	- all					10
Alberta	- with disposal wells		2.0	3.7	5.0	10
	- without disposal wells		3.0	5.5	7.5	10
British Columbia	- discharge to marine water:					
	Level A	1.15*				
	Level B	2.80**				
	Level C					15**
	- discharge to freshwater:					
	Level A	0.58*				
	Level B	2.80**				
	Level C					15**

* total oil
** nonvolatile oil

TABLE A-2 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Total Suspended Matter

		Maximum Deposits (lb/10^3 bbl·d^{-1})				
Region	Status	Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery - existing refinery that is altered or expanded		7.2	12.0	15.0	
	- existing refinery, unaltered portion		14.4	24.0	30.0	
Quebec	- new		7.19	12.0	15.0	
	- existing		14.4	24.0	30.0	
Ontario	- all					15
Alberta	- with disposal wells		4.8	8.0	10.0	25
	- without disposal wells		7.2	12.0	15.0	25
British Columbia	- discharge to marine water:					
	Level A	20				
	Level B	20				
	Level C	30				
	- discharge to freshwater:					
	Level A	20				
	Level B	20				
	Level C	30				

TABLE A-3 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Phenols

		Maximum Deposits (lb/10^3 bbl•d^{-1})				
Region	Status	Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery - existing refinery that is altered or expanded		0.3	0.55	0.75	
	- existing refinery, unaltered portion		0.6	1.1	1.5	
Quebec	- new		0.31	0.55	0.75	
	- existing		0.62	1.10	1.50	
Ontario	- all					0.02
Alberta	- with disposal wells		0.2	0.37	0.50	1.0
	- without disposal wells		0.3	0.55	0.75	1.0
British Columbia	- discharge to marine water:					
	Level A	0.023				
	Level B	0.06				
	Level C	0.2				
	- discharge to freshwater:					
	Level A	0.023				
	Level B	0.06				
	Level C	0.2				

TABLE A-4 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Ammonia Nitrogen

		Maximum Deposits (lb/10^3 bbl•d^{-1})				
Region	Status	Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery - existing refinery that is altered or expanded		3.6	5.7	7.2	
	- existing refinery, unaltered portion		5.0	8.0	10.0	
Quebec	- new		3.59	5.73	7.21	
	- existing		4.98	7.98	9.96	
Ontario	- all					10
Alberta	- with disposal wells		2.4	3.9	4.8	12.5
	- without disposal wells		3.6	5.7	7.2	12.5
British Columbia	- discharge to marine water:					
	Level A	0.576				
	Level B	1.87				
	Level C					15
	- discharge to freshwater*:					
	Level A	0.576				
	Level B	1.87				
	Level C					15

* as ammonia

TABLE A-5 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Sulphide

		Maximum Deposits (lb/10^3 bbl·d^{-1})				
Region	Status	Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery - existing refinery that is altered or expanded		0.1	0.3	0.5	
	- existing refinery, unaltered portion		0.2	0.6	1.0	
Quebec	- new		0.11	0.31	0.51	
	- existing		0.22	0.62	1.01	
Alberta	- with disposal wells		0.065	0.20	0.33	0.35
	- without disposal wells		0.1	0.30	0.50	0.35
British Columbia	- discharge to marine water*:					
	Level A	0.011				
	Level B	0.02				
	Level C					1.0
	- discharge to freshwater:					
	Level A	0.011				
	Level B	0.02				
	Level C					1.0

* sulphides and mercaptans as sulphur

TABLE A-6 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: pH

		Maximum Range	
Region	Status	Max. Daily	Continuous
Canada	- new refineries - existing refinery that is altered or expanded	6.0 to 9.5	
	- existing refinery, unaltered portion	6.0 to 9.5	
Quebec	- new	6.0 to 9.5	
	- existing	6.0 to 9.5	
Ontario	- all		5.5 to 9.5
Alberta	- with disposal wells	6.0 to 9.5	
	- without disposal wells	6.0 to 9.5	
British Columbia	- discharge to marine water:		
	Level A		6.5 to 8.5
	Level B		6.5 to 9.0
	Level C		6.5 to 9.0
	- discharge to freshwater:		
	Level A		6.5 to 8.5
	Level B		6.5 to 8.5
	Level C		6.5 to 9.0

TABLE A-7 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY STORMWATER

		Oil & Grease Deposits		Phenol Deposits		Total Suspended Matter	
Region***	Status	Conc.*	Limit**	Conc.*	Limit**	Conc.*	Limit**
Canada	- new refinery - existing refinery that is altered or expanded	1.0	25.0	0.1	2.5	3.0	75.0
	- existing refinery, unaltered portion	1.0	50.0	0.1	5.0	3.0	150.0
Quebec	- all	1.0	25.0	0.1	2.5	3.0	75.0
Alberta	- all	1.0	20.0	0.1	2.0	3.0	60.0

* lbs/10^4 Can. gal. of stormwater (Conc. = concentration)

** lbs/10^3 bbl of crude·d^{-1}

*** in British Columbia and Ontario, the limits on concentration in waste discharges will control discharge of contaminated stormwater

APPENDIX B

COMPLIANCE ASSESSMENT: ACTUAL AND AUTHORIZED DEPOSITS FOR 1983 ON A NATIONAL, REGIONAL AND INDIVIDUAL REFINERY BASIS

TABLE B-1 DEPOSITS AND COMPLIANCE ASSESSMENT (National 1983)

A. DEPOSITS

	Region	Atlantic	Quebec	Ontario		Western & Northern		Pacific & Yukon		National	
Yearly Average of Daily Deposits (kg/10^3 m^3 of crude oil)	Authorized Deposits (Atlantic and Quebec)	Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
Oil and Grease	17.1	9.2	17.9	13.8 (3.4)**	3.5 (1.7)	12.9	2.2	16.8 (4.66)	4.1 (2.49)	15.0 (4.0)	7.5 (2.1)
Total Suspended Solids	41.1	27.8	40.3	33.2 (10.2)	12.0 (2.6)	30.9	9.7	40.2 (19.0)	10.7 (8.04)	36.1 (12.1)	20.1 (5.3)
Phenols	1.7	0.39	0.62	1.4 (0.3)	0.0 (0.05)	1.3	0.44	1.7 (0.47)	0.67 (0.05)	1.5 (6.40)	0.38 (0.05)
Sulphide	0.67	0.032	0.13	0.5	-0.35	0.43	0.90	0.6	0.076	0.5	0.13
Ammonia Nitrogen	14.3	6.0	6.9	12.7	1.9	12.3	6.5	14.1	2.85	13.3	4.7

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines or Regulations*	Atlantic			Quebec			Ontario				Western & Northern			Pacific & Yukon				National			
	M	O	N	M	O	N	M	O	N	S	M	O	N	M	O	N	S	M	O	N	S
Oil and Grease	2	5	4	29	63	43	1	7	14	3	8	15	8	3	0	1	5	43	90	70	8
Total Suspended Solids	2	3	4	21	59	58	3	16	22	0	8	23	18	2	0	3	11	36	101	105	11
Phenols	2	0	4	6	20	17	0	0	0	0	6	0	0	7	8	15	0	21	28	36	0
Sulphide	0	0	0	1	0	1	0	0	0		11	0	0	3	1	0		15	1	1	
Ammonia Nitrogen	2	1	0	8	28	23	0	1	3		10	0	0	4	4	5		24	34	31	
pH			0			44			7				3			9				63	
Toxicity			3			7			1				1			12				24	
Total	8	9	15	65	170	193	4	24	47	3	43	38	30	19	13	45	16	139	257	333	19
Percentage of National	6	4	5	47	66	58	3	9	14	16	31	15	9	14	5	14	84				
Percentage of Time not in Compliance	4.2	0.5	1.5	21	3.9	4.0	0.8	0.2	0.6	4	9.7	3.6	2.3	5.2	1	4.7	9	7.6	2.3	2.8	7.6

b) Number of Monthly Amounts and Stormwater Deposits Exceeding the Limits by:	Atlantic	Quebec	Ontario	Western & Northern	Pacific & Yukon	National
0 to 24%	4	22	4	6	12	48
25 to 49%	1	15	1	6	4	27
50 to 99%	3	20	1	4	8	36
100 to 199%	0	6	0	8	6	20
+200%	0	2	1	5	5	27

* M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater amount.

** Deposits in brackets are for stormwater (annual - average).

	Region: Atlantic	Quebec	Ontario	Western & Northern	Pacific & Yukon	National
Reference Crude Rate (10^{3}m^3/d)	27.0	64.4	83.6	56.1	25.3	256.4
Status	existing	existing	existing 51.2 + expanded 9.5 + new 22.9	existing 26.8 + expanded 2.3 + new 27.0	existing 24.3 + expanded 1.0	existing 193.7 + expanded 12.8 + new 49.9
Percentage of Tests Reported	90	91	89	65	25	72

TABLE B-2 DEPOSITS AND COMPLIANCE ASSESSMENT (Atlantic Region -

		Refinery				
		Esso Petroleum Dartmouth	Irving St. John	Texaco Dartmouth	Ultramar Holyrood	Region
A. DEPOSITS						
Yearly Average of Daily Deposits (kg/10^3 m^3 of crude oil)	Authorized Deposits	Actual Deposits	Actual Deposits	Actual Deposits	Actual Deposits	Actual Deposits
Oil and Grease	17.1	9.3 ± 39%**	10.3 ± 25%	3.40 ± 21%	15.89 ± 44%	9.2
Total Suspended Solids	41.1	37.3 ± 38%	25.8 ± 25%	8.93 ± 40%	14.82 ± 13%	27.8
Phenols	1.7	0.84 ± 102%	0.12 ± 50%	0.12 ± 42%	0.42 ± 31%	0.39
Sulphide	0.6	0 ± 0%	0.06 ± 33%	0.01 ± 100%	0.06 ± 117%	0.032
Ammonia Nitrogen	14.3	3.1 ± 45%	9.2 ± 46%	3.09 ± 60%	0.24 ± 46%	6.0

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines*	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N
Oil and Grease	0	0	2	0	0	0	0	0	0	2	5	2	2	5	4
Total Suspended Solids	2	3	4	0	0	0	0	0	0	0	0	0	2	3	4
Phenols	2	0	4	0	0	0	0	0	0	0	0	0	2	0	4
Sulphide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammonia Nitrogen	0	0	0	2	1	0	0	0	0	0	0	0	2	1	0
pH			0			0			0			0			0
Toxicity			0			3			0			-			3
Total	4	3	10	2	1	3	0	0	0	2	5	2	8	9	15
Percentage of Region	50	33	67	25	11	20	0	0	0	25	56	13			
Percentage of Time not in Compliance	6.7	0.4	0.9	3.3	0.1	3.6	0	0	0	6.7	1.3	0.5	4.2	0.3	1.2

b) Number of Monthly Amounts Exceeding the Limits by:	Esso Petroleum Dartmouth	Irving St. John	Texaco Dartmouth	Ultramar Holyrood	Region
0 to 24%	1	2	0	1	4
25 to 49%	1	0	0	0	1
50 to 99%	2	0	0	1	3
100 to 199%	0	0	0	0	0
+200%	0	0	0	0	0

* M: Monthly amount; O: One-day amount; N: Maximum daily amount.

** Standard deviation expressed in percent.

	Refinery				
	Esso Petroleum Dartmouth	Irving St. John	Texaco Dartmouth	Ultramar Holyrood	Region
Reference Crude Rate (10^3 m^3/d)	10.03	13.20	3.18	1.19	27.1
Status	Existing	Existing	Existing	Existing	Existing
Number of Months in Operation	12	12	12	6	
Number of Tests Reported	1 192	948	2 202	249	4 591

TABLE B-3 DEPOSITS AND COMPLIANCE ASSESSMENT Quebec Region - 1983)

A. DEPOSITS

Yearly Average of Daily Deposits (kg/10^3 m^3 of crude oil)	Authorized Deposits	Refinery Gulf*** Montreal Actual Deposits	Esso Petroleum Montreal Actual Deposits	B.P. Anjou Actual Deposits	Petro-Canada*** Pointe-aux-Trembles Actual Deposits	Shell*** Montreal Actual Deposits	Ultramar St. Romuald Actual Deposits	Region Actual Deposits
Oil and Grease	17.1	9.89 ± 72%**	16.5 ± 29%	9.8 ± 22%	26.2 ± 25%	13.6 ± 57%	24.6 ± 46%	17.9
Total Suspended Solids	41.1	42.5 ± 67%	36.9 ± 31%	22.2 ± 19%	31.2 ± 24%	65.2 ± 54%	26.2 ± 63%	40.3
Phenols	1.7	0.53 ± 81%	0.44 ± 140%	0.24 ± 58%	1.1 ± 73%	0.57 ± 150%	0.49 ± 78%	0.62
Sulphide	0.6	0.084 ± 67%	0.30 ± 180%	0.16 ± 140%	0.14 ± 93%	0.056 ± 61%	0.10 ± 170%	0.13
Ammonia Nitrogen	14.3	1.93 ± 84%	4.29 ± 85%	13.0 ± 28%	5.7 ± 42%	9.3 ± 59%	9.74 ± 97%	6.9

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines*

	Gulf Montreal			Esso Petroleum Montreal			B.P. Anjou			Petro-Canada Pointe-aux-Trembles			Shell Montreal			Ultramar St. Romuald			Region		
	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N
Oil and Grease	2	4	3	5	3	3	0	0	0	11	20	12	3	5	6	8	31	19	29	63	43
Total Suspended Solids	5	18	19	3	3	2	0	0	0	2	0	0	10	33	32	1	5	5	21	59	58
Phenols	0	3	4	1	1	1	0	0	0	3	8	1	2	7	10	0	1	1	6	20	17
Sulphide	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Ammonia Nitrogen	0	0	0	0	1	0	2	3	2	0	1	2	2	7	10	4	16	9	8	28	23
pH																					
Toxicity			0			1			0			1			0			5			7
Total	7	25	27	10	8	8	2	3	2	16	29	16	17	52	62	13	53	78	65	170	193
Percentage of Region	11	15	14	15	5	4	3	2	1	25	17	8	26	30	32	20	31	41			
Percentage of Time not in Compliance	12	3.2	2.5	22	1.4	2.6	8.0	0.8	0.2	27	3.9	2.6	31	6.7	5.5	22	7.3	11	21	3.9	4.0

b) Number of Monthly Amounts Exceeding the Limits by:

	Gulf Montreal	Esso Petroleum Montreal	B.P. Anjou	Petro-Canada Pointe-aux-Trembles	Shell Montreal	Ultramar St. Romuald	Region
0 to 24%	3	7	1	4	4	3	22
25 to 49%	2	2	0	4	6	1	15
50 to 99%	1	0	1	7	4	7	20
100 to 199%	1	0	0	1	2	2	6
+200	0	1	0	0	1	0	2

---

* M: Monthly amount; O: One-day amount; N: Maximum daily amount.

** Standard deviation expressed in percent.

*** Combined petrochemical and refinery effluent.

	Refinery Gulf Montreal	Esso Petroleum Montreal	B.P. Anjou	Petro-Canada Pointe-aux-Trembles	Shell Montreal	Ultramar St. Romuald	Region
Reference Crude Rate (10^3 m^3/d)	11.1	11.8	7.9	14.2	15.6	12.7	64.4
Status	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Number of Months in Operation	12	9	5	12	11	12	
Number of Tests Reported	948	910	468	1 099	1 157	1 095	5 677

TABLE B-4 DEPOSITS AND COMPLIANCE ASSESSMENT (Ontario Region - 1983)

A. DEPOSITS

Yearly Average of Daily Deposits (kg/10^3 m^3 of crude oil)	Authorized Deposits (Esso, Shell-Corunna, Shell-Oakville)	Esso[(e)] Sarnia	Shell Corunna	Shell Oakville	Petro-Canada Oakville		Gulf[(a)] Mississauga		Suncor Sarnia			Petrosar[(b, e)] Corunna	Texaco Nanticoke	Region	
		Actual Deposits	Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits (Petrosar, Texaco)	Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
Oil and Grease	17.1	6.6 ± 58%**	4.2 ± 160%	1.9 ± 26%	15.4	0.7 ± 60%	15.8 (4.4)[(d)]	8.1 ± 39% (3.2 ± 44%)	13.2	1.8 ± 130%	8.6 (2.4)	1.4 ± 57%	0.43 ± 84% (0.2 ± 50%)	13.8 (3.4)	3.5 (1.7)
Total Suspended Solids	41.1	24.1 ± 29%	18.8 ± 423%	10.1 ± 21%	37.1	7.3 ± 45%	37.8 (13.1)	19.4 ± 69% (5.3 ± 58%)	31.7	6.3 ± 180%	20.6 (7.1)	4.7 ± 181%	-0.22 ± 70%[(c)] (1.2 ± 150%)	33.2 (10.2)	12.0 (2.6)
Phenols	1.7	0.051 ± 39%	0.008 ± 200%	0.01 ± 0%	1.5	0.01 ± 100%	1.6 (0.4)	0.1 ± 100% (0.1 ± 0.01%)	1.3	0.066 ± 0.01%	0.9 (0.2)	0.04 ± 150%	0.009 ± 127% (0.001 ± 0.002%)	1.4 (0.3)	0.04 (0.05)
Sulphide	0.6	0.0 ± 0%	-3.1[(c)] ± 48%	0.0 ± 0%	0.5	0.3 ± 0.01%	0.5	0.1 ± 100%	0.4	0.0 ± 0%	0.3	NM	0.02 ± 150%	0.5	-0.35
Ammonia Nitrogen	14.3	4.3 ± 120%	-2.9[(c)] ± 220%	3.2 ± 100%	13.5	3.5 ± 74%	13.6	2.8 ± 57%	12.4	1.5 ± 133%	10.3	1.7 ± 59%	1.1 ± 109%	12.7	1.9

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines or Regulations*

	Esso Sarnia			Shell Corunna			Shell Oakville			Petro-Canada Oakville			Gulf Mississauga				Suncor Sarnia			Petrosar Corunna			Texaco Nanticoke				Region			
	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	S	M	O	N	M	O	N	M	O	N	S	M	O	N	S
Oil and Grease	0	0	1	1	1	1	0	0	0	0	0	0	0	6	10	3	0	0	1	0	0	1	0	0	0	0	1	7	14	3
Total Suspended Solids	0	0	0	2	0	5	0	0	0	0	0	0	1	9	9	0	0	7	7	0	0	1	0	0	0	0	3	16	22	0
Phenols	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sulphide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	NM	NM	NM	0	0	0		0	0	0	
Ammonia Nitrogen	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0		0	1	3	
pH			0			1			0			0			3				0			1			2				7	
Toxicity			0			0			0			1			0				0			0			0				1	
Total	0	1	4	3	1	7	0	0	0	0	0	1	1	15	22	3	0	7	8	0	0	3	0	0	2	0	4	24	47	3
Percentage of Region	0	4	9	75	4	15	0	0	0	0	0	2	25	63	47	100	0	29	17	0	0	6	0	0	4	0				
Percentage of Time not in Compliance	0	0.1	0.3	5.0	0.1	1.5	0	0	0	0	0	1.2	1.7	0.8	0.9	8	0	0.7	0.5	0	0	0.1	0	0	0.1	0	0.8	0.2	0.6	4

b) Number of Monthly Amounts and Stormwater Deposits Exceeding the Limits by:

	Esso Sarnia	Shell Corunna	Shell Oakville	Petro-Canada Oakville	Gulf Mississauga	Suncor Sarnia	Petrosar Corunna	Texaco Nanticoke	Region
0 to 24%	0	1	0	0	3	0	0	0	4
25 to 49%	0	1	0	0	0	0	0	0	1
50 to 99%	0	0	0	0	1	0	0	0	1
100 to 199%	0	0	0	0	0	0	0	0	0
+200%	0	1	0	0	0	0	0	0	1

a) A limited number of cooling-water analyses (usually 4 to 5/month for each cooling water trap outfall) are conducted for oil and grease and phenols. Cooling water suspended solids, sulphide, and ammonia nitrogen are not monitored. Yearly average loadings may be higher than indicated.
b) Petrosar did not monitor the level of sulphide in its effluent and thus was in violation of the Regulations.
c) See discussion of the individual refineries for explanation of the negative values.
d) Deposits in bracket are for stormwater (annual - average).
e) Combined refinery and petrochemical effluents.

* M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater amount.
** Standard deviation expressed in percent.
NM - Not Monitored

	Refinery								
	Esso Sarnia	Shell Corunna	Shell Oakville	Petro-Canada Oakville	Gulf Mississauga	Suncor Sarnia	Petrosar Corunna	Texaco Nanticoke	Region
Reference Crude Rate (10^3 m^3/d)	15.3	9.5	4.8	8.5	12.3	12.7	11.0	11.9	83.6
Status	Existing	Existing	Existing	Existing 6.7 + Expanded 1.8	Existing 10.4 + Expanded 1.9	Existing 6.9 + Expanded 5.8	New	New	Existing 51.2 + Expanded 9.5 + new 22.9
Number of Months in Operation	12	12	6	12	12	12	12	12	
Number of Tests Reported	1 572	998	474	1 614	2 210	1 210	1 751	1 488	11 317

TABLE B-5 DEPOSITS AND COMPLIANCE ASSESSMENT (Western & Northern Region - 1983)

	Refinery															
		Gulf Edmonton	Gulf(a, b) Moose Jaw	Esso Petroleum Norman Wells	Shell Bowden	Shell (a, b) Winnipeg	Texaco Edmonton	Co-op (a, b, c) Regina		Gulf Calgary			Husky Lloydminster	Esso Petroleum Edmonton	Turbo Balzac	Region	
A. DEPOSITS																	
Yearly Average of Daily Deposits (kg/10³ m³ of crude oil)	Authorized Deposits (Gulf-Edmonton; Gulf-Moose Jaw; Esso-Norman Wells; Shell-Bowden, Shell-Winnipeg, Texaco)	Actual Deposits	Actual Deposits	Actual Deposits		Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits (Husky, Esso-Edmonton; Turbo)	Actual Deposits	Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
Oil and Grease	17.1	0.14 ± 64%***	1.7 ± 65%	26.4 ± 52%	no discharge	7.5 ± 89%	1.6 ± 62%	14.3	3.1 ± 16%	15.8	7.9 ± 42%	8.6	deep-well injection	1.7 ± 82%	0.19 ± 74%	12.9	2.2
Total Suspended Solids	41.1	3.83 ± 170%	3.4 ± 29%	206.5 ± 132%		7.7 ± 114%	9.7 ± 50%	34.4	7.3 ± 37%	38.0	17.9 ± 58%	20.6		10.2 ± 40%	3.5 ± 120%	30.9	9.7
Phenols	1.7	0.013 ± 77%	0.015 ± 47%	0.57 ± 35%		1.3 ± 69%	0.15 ± 47%	1.4	2.7 ± 37%	1.6	0.11 ± 109%	0.86		0.009 ± 78%	0.025 ± 76%	1.3	0.44
Sulphide	0.6	0.001 ± 500%	1.1 ± 118%	0.23 ± 83%		0 ± 0%	0.21 ± 67%	0.48	6.9 ± 146%	0.53	0.018 ± 94%	0.29		0.024 ± 67%	0.43 ± 33%	0.43	0.90
Ammonia Nitrogen	14.3	0.27 ± 63%	0.81 ± 33%	1.4 ± 71%		66.1 ± 68%	1.48 ± 31%	13.0	15.2 ± 30%	13.7	0.65 ± 71%	10.3		0.61 ± 48%	0.64 ± 66%	12.3	6.5

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines or Regulations*	Gulf Edmonton			Gulf Moose Jaw			Esso Petroleum Norman Wells			Shell Bowden			Shell Winnipeg			Texaco Edmonton			Co-op Regina			Gulf Calgary			Husky Lloydminster			Esso Petroleum Edmonton			Turbo Balzac			Region		
	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N
Oil and Grease	0	0	0	0	-	-	6	13	5		-		1	-	-	0	0	0	0	-	-	0	0	1		-		1	2	2	0	0	0	8	15	8
Total Suspended Solids	0	0	0	0	-	-	8	22	16		-		0	-	-	0	2	1	0	-	-	0	0	0		-		0	0	1	0	0	0	8	23	18
Phenols	0	0	0	0	-	-	0	0	0		-		2	-	-	0	0	0	4	-	-	0	0	0		-		0	0	0	0	0	0	6	0	0
Sulphide	0	0	0	2	-	-	1	0	0		-		0	-	-	0	0	0	2	-	-	0	0	0		-		0	0	0	6	0	0	11	0	0
Ammonia Nitrogen	0	0	0	0	-	-	0	0	0		-		7	-	-	0	0	0	3	-	-	0	0	0		-		0	0	0	0	0	0	10	0	0
pH			1			0			0		-				0			1			0			0		-				0			1			3
Toxicity			0			NR**			0		-				-			0			-			0		-				1			NR			1
Total	0	0	1	2	-	-	15	35	21		-		10	-	-	0	1	2	9	-	-	0	0	1		-		1	2	4	6	0	1	43	38	29
Percentage of Region	0	0	3.3	5	-	-	35	92	70		-		23	-	-	0	3	7	21	-	-	0	0	3.3		-		2	5	13	14	0	3.3			
Percentage of Time not in Compliance	0	0	0.04	8.0	-	-	37	21	10		-		25	-	-	0	0.2	0.2	45	-	-	0	0	0.05		-		1.7	0.3	0.3	11	0	0.1	9.7	3.6	2.3

b) Number of Monthly Amounts and Stormwater Deposits Exceeding the Limits by:	Gulf Edmonton	Gulf Moose Jaw	Esso Petroleum Norman Wells	Shell Bowden	Shell Winnipeg	Texaco Edmonton	Co-op Regina	Gulf Calgary	Husky Lloydminster	Esso Petroleum Edmonton	Turbo Balzac	Region
0 to 24%	0	0	0	-	1	0	1	0	-	1	3	6
25 to 49%	0	0	0	-	1	0	2	0	-	0	3	6
50 to 99%	0	0	0	-	1	0	3	0	-	0	0	4
100 to 199%	0	0	5	-	2	0	1	0	-	0	0	8
+200	0	2	10	-	5	0	2	0	-	0	0	19

a) Insufficient number of tests reported rendered the one-day and the maximum daily amounts meaningless.
b) Effluent receives offsite treatment at municipal facility which is considered to give equivalent treatment for all parameters except ammonia nitrogen.
c) Testing done tri-monthly.

* M: Monthly amount; O: One-day amount; N: Maximum daily amount.
** NR: Not Reported.
*** Standard deviation expressed in percent.

	Refinery											
	Gulf Edmonton	Gulf Moose Jaw	Esso Petroleum Norman Wells	Shell Bowden	Shell Winnipeg	Texaco Edmonton	Co-op Regina	Gulf Calgary	Husky Lloydminster	Esso Petroleum Edmonton	Turbo Balzac	Region Overall
Reference Crude Rate (10^3 m^3/d)	12.23	1.12	0.51	0.95	4.44	3.74	6.36	1.57	2.45	20.86	3.71	56.1
Status	Existing	Existing	Existing	Existing	Existing	Existing	Existing 4.29 + Expanded 2.07	Existing 1.33 + Expanded 0.24	New	New	New	Existing 26.8 + Expanded 2.31 + new 27.02
Number of Months in Operation	12	7	12	12	9	12	12	10	12	12	12	
Number of Tests Reported	661	40	217	-	490	1 403	24 (c)	954	-	1 145	804	5 738

TABLE B-6 DEPOSITS AND COMPLIANCE ASSESSMENT (Pacific & Yukon Region - 1983)

A. DEPOSITS

Yearly Average of Daily Deposits (kg/10³ m³ of crude oil)	Authorized Deposits (Esso-Ioco; Gulf-Port Moody; Gulf-Kamloops; Husky-Prince George; Petro-Canada; Shell)	Refinery: Esso Petroleum Ioco Actual Deposits	Gulf (b) Port Moody Actual Deposits	Gulf (b) Kamloops Actual Deposits	Husky (b) Prince George Actual Deposits	Husky (b) Prince George Actual Deposits	Petro-Canada (a) Taylor Actual Deposits	Shell (b) Burnaby Actual Deposits	Chevron (b) North Burnaby Authorized Deposits	Chevron (b) North Burnaby Actual Deposits	Region Authorized Deposits	Region Actual Deposits
Oil and Grease	17.1 (4.76)	0.73 ± 82%**** (6.41 ± 91%)***	2.52 ± 66% (0.27 ± 63%)	3.99 ± 60%	2.85 ± 50%	2.85 ± 50%	1.74 ± 67% (0.02 ± 250%)*	6.51 ± 36% (1.72 ± 41%)	15.3 (4.3)	9.64 ± 60% (1.59 ± 63%)	16.8 (4.66)	4.1 (2.49)
Total Suspended Solids	41.1 (14.27)	9.07 ± 29% (22.10 ± 33%)	9.51 ± 7% (2.26 ± 50%)	9.41 ± 52%	0.06 ± 133%	0.06 ± 133%	Negative (2.88 ± 192%)	8.57 ± 54% (2.63 ± 59%)	37.0 (12.8)	19.8 ± 60% (4.48 ± 70%)	40.2 (14.0)	10.7 (8.04)
Phenols	1.7 (.476)	0.28 ± 118% (0.044 ± 64%)	0.53 ± 66% (0.004 ± 50%)	1.46 ± 164%	0.02 ± 250%	0.02 ± 250%	0.22 ± 286% (0.04 ± 325%)	0.07 ± 114% (0.028 ± 182%)	1.5 (0.43)	2.11 ± 79% (0.12 ± 67%)	1.7 (0.47)	0.67 (0.05)
Sulphide	0.6	0.00 ± 0%	0.11 ± 73%	0.41 ± 100%	0.0 ± 0%	0.0 ± 0%	0.42 ± 36%	0.0 ± 0%	0.5	0.02 ± 250%	0.6	0.076
Ammonia Nitrogen	14.3	2.58 ± 33%	0.36 ± 6%	0.17 ± 106%	4.91 ± 30%	4.91 ± 30%	12.1 ± 74%	3.55 ± 58%	13.5	1.98 ± 59%	14.1	2.85

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines**

	Esso Petroleum Ioco				Gulf (b) Port Moody				Gulf (b) Kamloops			Husky (b) Prince George		
	M	O	N	S	M	O	N	S	M	O	N	M	O	N
Oil and Grease	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Total Suspended Solids	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Phenols	0	0	0	0	0	0	0	0	1	2	3	0	0	0
Sulphide	0	0	0		0	0	0		1	1	0	0	0	0
Ammonia Nitrogen	0	0	0		0	0	0		0	0	0	0	0	0
pH			2				0				2			1
Toxicity			2				0				NR			9
Total	0	0	4	15	0	0	0	0	2	3	5	0	0	10
Percentage of Region	0	0	9	94	0	0	0	0	10	23	11	0	0	22
Percentage of Time not in Compliance	0	0	1.4	42	0	0	0	0	5.7	2.9	3.0	0	0	3.6

	Husky (b) Prince George			Petro-Canada (a) Taylor				Shell (b) Burnaby				Chevron (b) North Burnaby				Region			
	M	O	N	M	O	N	S	M	O	N	S	M	O	N	S	M	O	N	S
Oil and Grease	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	3	0	1	5
Total Suspended Solids	0	0	0	0	0	0	1	0	0	0	0	2	0	3	0	2	0	3	11
Phenols	0	0	0	1	0	1	0	0	0	0	0	5	6	11	0	7	8	15	0
Sulphide	0	0	0	2	0	0		0	0	0		0	0	0		3	1	0	
Ammonia Nitrogen	0	0	0	4	4	5		0	0	0		0	0	0		4	4	5	
pH			1			0				0				4				9	
Toxicity			9			0				1				0				12	
Total	0	0	10	7	4	6	1	0	0	1	0	10	6	19	0	19	13	45	16
Percentage of Region	0	0	22	37	31	14	6	0	0	2		53	46	42	0				
Percentage of Time not in Compliance	0	0	3.6	12															

b) Number of Monthly Amounts and Stormwater Deposits Exceeding the limits by:

	Esso Petroleum Ioco	Gulf (b) Port Moody	Gulf (b) Kamloops	Husky (b) Prince George	Husky (b) Prince George	Petro-Canada (a) Taylor	Shell (b) Burnaby	Chevron (b) North Burnaby	Region
0 to 24%	3	0	0	0	0	5	0	4	12
25 to 49%	2	0	0	0	0	1	0	1	4
50 to 99%	6	0	0	0	0	1	0	1	8
100 to 199%	1	0	1	0	0	1	0	3	6
+200%	3	0	1	0	0	0	0	1	5

a) Combined refinery and gas plant effluent.
b) Effluent receives additional treatment off site.

* Stormwater combined with process effluent.
** M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater amount.
*** Actual deposits in bracket are for stormwater (annual average).
**** Standard deviation expressed in percent.
NR: Not Reported.

	Refinery: Esso Petroleum Ioco	Gulf Port Moody	Gulf Kamloops	Husky Prince George	Husky Prince George	Petro-Canada Taylor	Shell Burnaby	Chevron North Burnaby	Region
Reference Crude Rate (10³ m³/d)	6.7	6.5	1.6	1.2	1.2	2.0	4.0	4.8	25.3
Status	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing 3.8 + Expanded 1.0	Existing 24.3 + Expanded 1.0
Number of Months in Operation	11	12	5	12	12	12	12	12	
Number of Tests Reported	442	430	174	278	278	287	539	433	2 583